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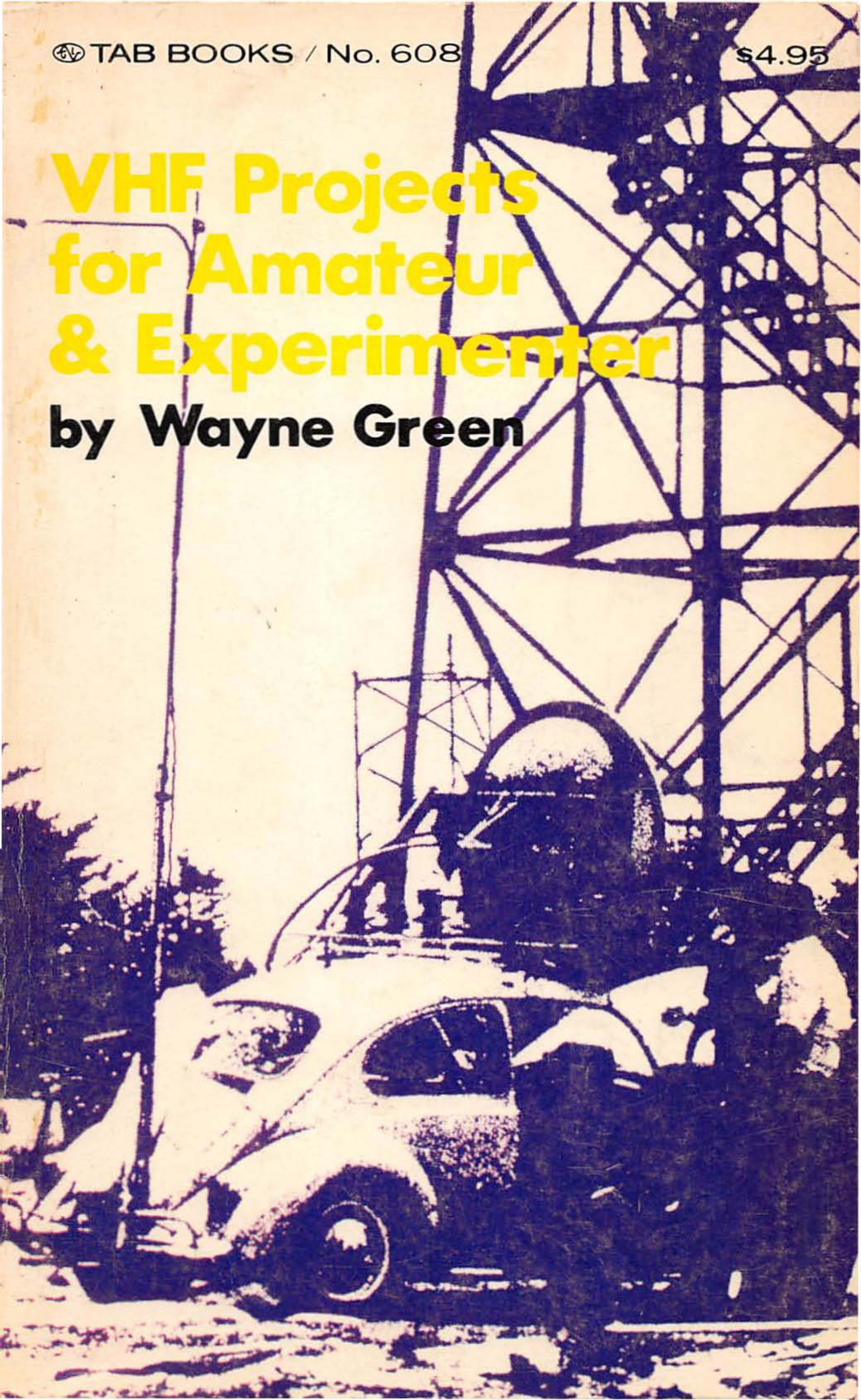
VHF Projects for Amateur & Experimenter

by Wayne Green



VHF PROJECTS FOR AMATEUR & EXPERIMENTER

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Preface

As the lower frequency ham bands become more and more crowded, the enthusiastic, enterprising amateur has no choice but to look for greener pastures on the very high frequencies. If you're ready to accept the challenge, the projects in this book will help you make the move. Each project, selected from the many articles published in 73 Magazine during the past several years, tells and shows how to build a useful piece of equipment or modify existing and surplus gear. Some are relatively simple; others are more complex—but there's a variety to match the skill of an oldtimer and test the budding ability of the tyro amateur.

Some projects tell you how to build a complete station, either fixed or portable. Others relate to more specific gear which will augment an existing setup. Also, there are antenna projects that will aid in achieving more effective communications on these frequencies. Regardless of your longevity in official "hamdom," you'll find in the following pages all the information needed to begin your move up to VHF.

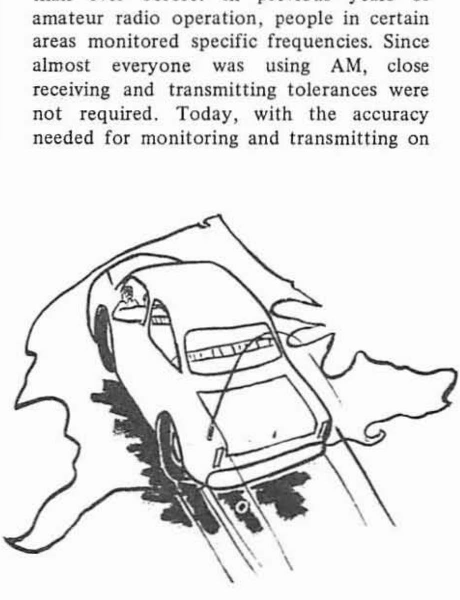
The Editors

Contents

VHF FM & You

The past few years have shown a marked increase in the number of amateurs operating on the 50 MHz, 144 MHz, and higher frequency bands. Many of these amateurs are using surplus or obsolete commercial FM equipment. This rise in FM activity is due to several factors, including the availability of equipment and the need for reliable single-frequency communications. The availability of equipment is due to two prime factors: The "splitting" of commercial FM channels has rendered many older units unsuitable for commercial use. Also, recent trends in miniaturization have made many units obsolete in terms of size, reliability, and battery-power consumption.

The need for a reliable single-channel system stems from several factors: The average American is much more "mobile" than ever before. In previous years of amateur radio operation, people in certain areas monitored specific frequencies. Since almost everyone was using AM, close receiving and transmitting tolerances were not required. Today, with the accuracy needed for monitoring and transmitting on specified SSB frequencies, it is becoming less and less popular to do so. Of course, there are a few frequencies that are monitored in certain areas, but these are relatively rare. Also, the congestion on the lower frequencies is increasing, thus requiring more and more power in both mobile and fixed-station equipment.



The average American is much more mobile than ever before.

The trend is thus towards a universal fixed-frequency type of operation in cases where reliability and performance are required. This has been met by using certain specified frequencies and fixed-frequency FM equipment. The most popular of the universally accepted VHF frequencies are 52.525 and 146.94 MHz.

Operating on VHF FM

Operation of VHF FM is very much like operation on the lower frequencies, and yet it is very different. It is like AM, SSB, and even CW in that there is much ragchewing, many technical discussions, and even emergency and traffic nets. You can call your buddy, check out equipment, and handle traffic and emergency situations. It is quite unlike SSB, AM, and CW in that there is no need to retune the transmitter and receiver every time you operate; there is usually no background noise whenever the frequency is not in use (almost every piece of commercial FM gear has a noise-stopping squelch); high power is not needed for general use; and the frequency is almost constantly monitored.

Although the sudden popularity of FM and the increasing availability of specially designed gear threaten to change the picture, the equipment used by the average FM'er has typically been obsolete commercial equipment previously used by police, fire, taxi, utility, and other groups. This equipment has a power *output* of from a few milliwatts to nearly 100 watts, and a frequency selection of from one to four crystal-controlled channels. The design of the equipment is excellent. The receivers

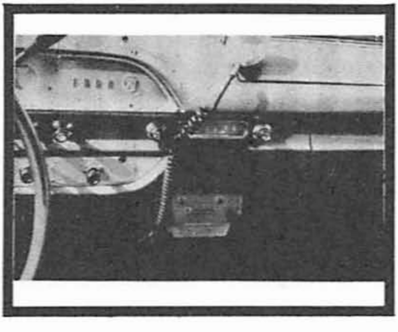
often have sensitivity figures of 0.5 μV (for 20 dB of noise quieting) or better. Operation of the equipment is quite simple, for it was originally designed to be used by nontechnical people in business or emergency situations. The controls usually consist of an on-off-volume control, a squelch control, and a push-to-talk microphone.

Many amateurs operate using "wideband" or ±15 kHz deviation. Some amateurs in certain areas are gradually shifting to "narrowband" or ±5 kHz deviation. This poses no real difficult problems, for narrowband signals can be received on wideband equipment (with an apparent loss of audio volumeand subsequent decrease in signal-to-noise ratio). Wideband signals can rarely be received on narrowband equipment without adjustment of the transmitting or receiving equipment, however.

Almost every metropolitan area now has at least one repeater system which will pick up and rebroadcast signals. In most cases, the input of these repeaters is 146.34 MHz and the output is 146.94 MHz. But in areas of extreme spectrum congestion, other frequency pairs are used.

The range of units (without using a repeater) varies with terrain and power output, as well as the type of antenna used. It has been my experience that the average unit now in use by the amateur FM'er (10W output with a quarter-wavelength whip) has about a 15-mile range of communication.

FM equipment is generally reliable, and when it does become necessary to either repair or service, it is relatively easy to work on. Many units use common tube types in both the receiving and transmitting portions, thus eliminating a parts scarcity problem.



Many taxi companies trade in older units or sell them to individual drivers; but the units often get passed along more than once, and they come out the worst for wear in the shuffle.

Most units are divided into three distinctive portions: transmitter, receiver, and power supply, with interconnecting cables. These "strips" are often interchangable between units, from base station to mobile and from mobile to base station. Trunk mount units are usually "wife approved," for the control head and speaker take up very little room in the car. However, there is very little difference in performance of trunk mount and dash mount units of the same type.

Acquisition of Equipment

The old Bugs Bunny cartoons used to start with Elmer Fudd reading a recipe for rabbit stew. He would quote the first instruction as "First, catch a wabbit." Well, the first instruction in the recipe for good amateur FM'ing is to first catch the unit.

Local sources of equipment vary. The best place to start is another amateur who is already active on VHF FM. Many FM'ers keep spare units around for trading and helping out newcomers. If you don't know any active FM'er in your neighborhood, then you will have to start looking elsewhere. In some localities the police and fire forces are possible sources. However, many departments either trade in older equipment on newer models, or they sell the units to the

members of the department for monitor receivers and for auxiliary squad work.

Another possible source is taxi companies. The two-way radio is the life-blood of the taxi driver, so most cars are usually equipped. Herein problems also lurk. Many taxi companies trade in older units or sell them to the individual drivers. The units sold to the drivers often get resold to other drivers and so on until the unit is either so old or so beat up that it is good only for a boat anchor.

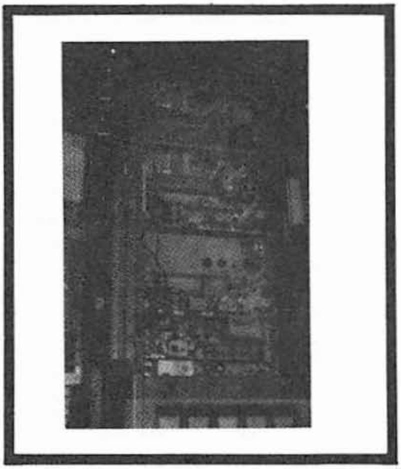
The modern railroader is quite dependent upon communications, so FM gear is found around rail yards. Railroading is hard business, and the equipment often sees rough service. However, many amateurs have been able to obtain obsolete equipment from railroads. If there is a repair center in your area, check with the purchasing agent there. If not, talk with someone who works for the railroad and find out who takes care of the radios in your locality.

Sometimes two-way radio repair shops are subcontractors to the major manufacturers and some even buy and sell two-way equipment. However, many of these shops have a market for monitor receivers, system spares, and the like, and do not like to dispose of any extra pieces of equipment at low prices. There is always a chance, though, and even if the personnel do not have any units to dispose of, they often have information as to where such units can be obtained.

Utility companies usually buy equipment from the two-way manufacturers on an outright basis and seldom trade in older equipment. Often entire fleets of equipment are retired at the same time. Some companies will sell one or two units at a time while others will only sell in lots of 5, 10, 15 or more units. In these cases it is necessary for a group or club to purchase the units in order to meet the minimum purchase requirements. Of course, some utility companies have been known to give the units to a club for distribution to the membership – but such cases are the exception.

It is possible to purchase either portions of units or complete systems from companies who specialize in the surplus FM market.

However, prices are usually higher than would be paid if obtained locally. One advantage of dealing with a surplus house is



that you have some recourse if you're not happy with your purchase within a reasonable period. Several of the surplus FM suppliers offer money-back equipment guarantees. Also, these companies often have a supply of schematics and other information on the equipment.

If you have a selection, always pick a mobile with a transistorized power supply over a vibrator (and a vibrator over a dynamotor, if in the same power output class). Always remember that power output is the measure of FM gear, not power input as in other equipment. If the unit is intended for fixed-station use, pick out the highest powered unit in best condition. If a choice is available between several units pick the newest type.

General Conversion Techniques

The first step in conversion is to determine the frequency range of your unit. If the source is known, it is a simple matter to check the operating frequency. If the source is not known, a look at the final tank will usually give a clue. Of course, the major manufacturers have a definite system of marking the frequency ranges of the equipment.

The first step in the actual conversion is to acquire a set of crystals on the proper frequency. This is best accomplished by ordering commercial grade crystals from a crystal company that typically supplies crystals to the two-way industry. I highly recommend International Crystal for several reasons: They can supply crystals of the

correct cut and frequency for multiplication when given the manufacturer of the equipment and the manufacturer's crystal type; International guarantees crystals for correct operation; and they give excellent service in terms of turnaround time and warranty replacement. Regardless of the source of the crystals, it is important that they are of the correct cut. If the crystal was not designed for the oscillator circuit used in the equipment, it may not "pull" onto the correct frequency if it oscillates at all.

The next step is getting the heater strings on the correct voltage. If the unit is to be used as a base station with an external ac supply this step is unnecessary, for the correct heater voltage can be supplied from the ac supply.

Many 6V units have the heater strings divided into two 6V sections with approximately the same current requirements for each section. If this is the case, conversion to 12V involves merely lifting the ground side (if any) on one half of the heater strings and forming a series–parallel arrangement. It is necessary, however, to retain a balance in current requirements. That is, do not put a section requiring 5A of heater current in series with a section requiring 6.5A, etc. A small difference can be tolerated, but the better the match, the better the performance. In units where the "strings" do not exist, it is necessary to calculate the heater current requirements and then develop the necessary series–parallel arrangement.

The power supply is the next area of conversion. Fortunately, most transistorized power supplies are found in either 12V only or 6/12V combination units. Thus, I will not attempt to cover them here. Dynamotor units may or may not prove to be difficult to convert from 6 to 12V operation. The cheapest method is to replace the dynamotor with a 12V surplus unit. The DM-35 works very well in higher powered units (50–60W), and other units may be used for lower powered equipment.

The receiver power supply is almost always a vibrator supply, even in dynamotor units. The simplest modification for this supply is to pick up 6V across one of the filament strings. A 2W dropping resistor of 20–47Ω will have to be put in series with the vibrator coil if the vibrator itself is driven directly from 12V.

Vibrator units are generally of two types: Lower powered units (<15W) use a single transformer to provide voltage for both receiver and transmitter B+ lines. Higher powered units use two transformers, one for low B+ and one for high B+. In the case of the single transformer unit, the power supply may be connected across the lower leg of the heater string. In this case, allow for the current required by the power supply when setting up the heater strings or place a resistor of the correct size across the other heater string. In the case of two transformers, each one may be placed across separate heater strings. Make sure that the circuitry formerly grounded goes to the 6V point in the section which is connected across the "high" heater string (the string which is not grounded).

The rectifiers used in older FM equipment are usually of the selenium type. If higher voltage is required, or if any one of the rectifiers is defective, replace the entire rectifier with the silicon type. This usually results in higher transmitter output and lower power supply heating.

Low-band conversions. Units which were originally designed for the 25–30 MHz range will, of course, work on 10 meters without any modifications. The only thing which needs to be done is to put in the necessary crystals and keep the deviation below the maximum allowed by the FCC. Units designed for the 30–40 MHz range will also usually work on 10 meters without modifi-

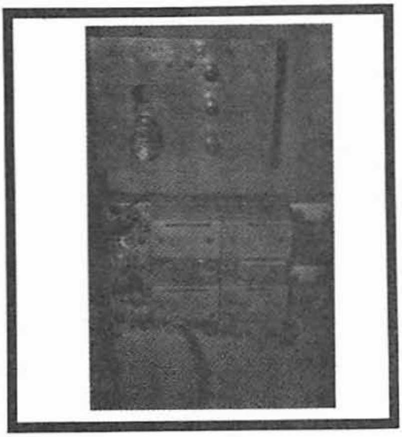
The transmitter final grid and tank coils may be slightly squeezed together to lower the frequency.

cation. If the receiver will not tune down to 29 MHz, it is usually necessary to place small capacitors (a few picofarads will usually do) across the coils in the rf section. The transmitter final grid and tank coils may be slightly squeezed together to lower the frequency.

Use of the 30–40 MHz units on 6 meters sometimes requires a substantial amount of modification. Fortunately, only the rf and first mixer sections need modification in the receiver. These coils must be reduced by either removing turns or decreasing the capacity across the coils. A grid dip oscillator is a must. The entire transmitter section must be modified. Each coil must be reduced in size until it will tune to the correct frequency.

The 40–50 MHz units can be used on 52.525 MHz without modification. All that is required is the proper crystals. If, for some reason, the unit will not tune up to 52 MHz, it may be necessary to reduce the capacity across the receiver rf coils and slightly spread the turns of the final tank coil to bring them within the tuning range.

High-band conversions. Units in the 144–170 MHz range will usually tune up on 146.94 MHz without modification. Units that require modification can usually be brought within range in the following manner: The receiver rf coils may be padded within range by putting small Mylar capacitors of 2–5 pF across each section. The receiver oscillator coil may require as much as 20 pF across it. (Try for proper operation without this capacitor before adding it.)



The only transmitter stages usually requiring modification are the driver and final sections. The driver may be brought within range by either squeezing together the turns of the coil (if a coil is used) or by the addition of approximately 5 pF across the tuning capacitor (if parallel lines are used). In the cases where there is not enough capacity in the final tank circuit or where adjustable plates do not exist, it is necessary to add capacitance here also. The simplest manner is to make a capacitor from about 3 in. of RG-58/U coax. This coax is attached with the shield side to one line and the center to the other. The coax may be trimmed about ¼ in. at a time until the final tank is resonant with the tuning slider about ¼ in. from the end.

General tuning instructions. For the most part, the FM unit is tuned in each stage for maximum output. Most equipment has either a central metering point or a test jack for each stage. In all cases a VOM may be used as a visual indication. Normally a 0–3V scale is sufficient. The Motorola units may be measured with either a VOM or a 50 μA meter. Generally, the only exception to the "maximum output" rule is the discriminator frequency, which is adjusted for a zero reading.

The receiver should be tuned starting with the meter at the second limiter test point. As the tuning progresses, it will become necessary to first reduce the signal input to the receiver and then to switch to the first limiter test point. As the second limiter approaches saturation, the reading will begin to decrease, thus giving a false reading. That is why it is necessary to reduce the signal input. The same thing holds true for the first limiter, but it does not go into saturation as easy as the second limiter and is therefore a better indication at higher signal levels.

When starting from scratch it is usually necessary to begin receiver tuning with the low i-f stage. In almost every Motorola FM unit this stage is at 455 kHz. The low i-f coils are adjusted for maximum reading at the second limiter test point (make sure to keep the signal level low enough to prevent saturation). At this time also adjust the discriminator secondary for zero reading at the discriminator test point.

The next stage to be tuned is the high i-f stage. This stage may be first tuned by

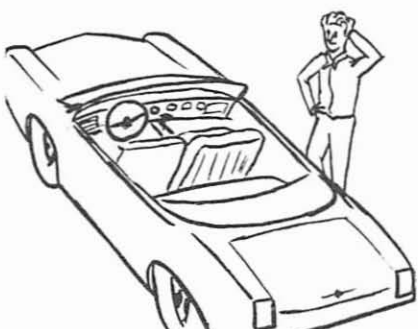
injecting a signal at the i-f and adjusting for maximum reading at the second limiter test point. These adjustments may be "touched up" when the carrier frequency is being received.

The rf stages can usually be adjusted by inserting a signal at the antenna jack at a fairly high level and adjusting the coils for maximum reading at either the second limiter or first limiter test point (taking care not to saturate the stage being measured). In cases where a signal cannot be forced through from the antenna jack, it is necessary to use an injection probe of some type and start at the final rf stage and work towards the antenna.

The carrier frequency may be adjusted by metering the discriminator test point and adjusting the crystal warp capacitor or coil until a zero reading is obtained.

The first step in tuning the transmitter is to put the high–low switch located near the final amplifier section in the low position. Or, if the unit does not have such a switch, disconnect the plate connections to the final amplifier tube. This is to protect the final from damage from prolonged periods of tuneup.

Actual tuning begins with the oscillator section and works toward the final. Each stage is tuned for maximum output. A metering point is usually provided at each stage. If the unit has been modified, especially if modified from 30–40 MHz to 6 meters, it will be necessary to check the output frequency from each multiplier stage. After every stage (except the final and driver) has been tuned, replace the final tube if it was removed. Tune the driver, final grid, and final plate circuits for maximum output. Next, go back through the unit and touch up the various stages.



In mobile installations the best place for the antenna is the center of the roof.

Antennas

The vast majority of FM operation is with vertically polarized antennas. These range from the simple quarter-wave whip to corner reflectors and yagis. The most popular mobile antenna for both 10 and 6 meter FM activity is the stainless steel whip with spring base. Next in popularity are the shortened antennas made by Antenna Specialists Company and others. The latter type may be mounted in the center of the roof or on the rear deck for better isotropic radiation.

Three types of antennas enjoy popularity with FM amateurs operating on 2 meters. They are the quarter-wave whip, the coaxial antenna, and the 5/8-wave, 3 dB gain antenna manufactured by Antenna Specialists and others. The quarter-wave whip can usually be purchased for under $5. The coaxial antenna can be purchased for around $20. The 3 dB gain antennas cost about $25, but they will effectively double the output power.

Base station antennas are also vertically polarized, and come in various sizes and shapes. The antenna generally in use on 10 and 6 meters is the groundplane, with the coaxial collinear antenna running a distant second. Both these antennas may be either purchased or constructed by the amateur.

In general, the following can be stated about VHF FM antennas: In mobile installations the best place for the antenna is the center of the roof. The next place is the rear deck or trunk lid; next comes the fender, and finally a bumper mount. In base stations, the rule is the higher the better while keeping line losses down. Remember that even the best coax has a great deal of loss at 2 meters and higher. If possible, use a very good grade of foam coax. Of course there are lines available with extremely low losses, but these are quite expensive and extremely hard to work with.

Glossary

Whenever an amateur first starts out he must learn the jargon used on the bands. The same is true when starting out on VHF FM. As an aid, twenty of the more common terms and their usual meanings are listed below.

Channel Guard: A registered trademark of General Electric for a system of *continuous tone squelch.*

Coffin units: FM units manufactured in the late 1940s and early 1950s such as the Motorola 30D which consisted of separate receiver and transmitter units housed in cabinets with rounded tops which resembled coffins.

Control heads: The small box-like unit containing the off-on-volume control, squelch control, and microphone connections of a trunk-mounted mobile unit. The control head connects to the unit via a multiconductor cable.

Continuous tone squelch (CTS): A system wherein a low, subaudible tone is transmitted continuously with the voice transmission. This tone activates a reed in the receiver which, in turn, allows the squelch to operate. If the tone is not present, the receiver remains muted. This system allows only the desired stations (those with the correct tone frequency) to be received. Provision is normally made to use either conventional squelch or an unsquelched monitor position.

Deviation: The amount the modulated carrier varies from the center frequency. During half of the modulating cycle the deviation is positive and during the other half the deviation is negative. Commercial standards now call for ±5 kHz (narrowband). Most amateur operation is ±15 kHz (wideband).

Discriminators: The discriminator serves to convert the FM signal to AM and then demodulate the AM signal into audio. It is analogous to the diode detector in AM gear and the product detector in SSB gear.

High band: The slang term applied to the commercial band from 148 to 172 MHz.

IDC (Instantaneous Deviation Control): Motorola tradename for the potentiometer which acts as an "audio gain" which in turn controls the level of peak deviation.

Limiter: A circuit i-f which saturates with a fairly low incoming signal, keeping the audio output from the discriminator at a constant level (similar to AVC in an AM unit). This circuit is needed because the audio output from a discriminator is directly proportional to the signal input, thereby varying with any change in signal level.

Low Band: The commercial band from 30 to 50 MHz.

Motrac: A registered trademark of Motorola for its series of mobile equipment utilizing transistorized receivers and hybrid transmitters.

Permakay: A Motorola trademark for its line of selective i-f filters. These are of two types, wideband (marked with a type number ending with the letter "W") and narrowband (marked with a type number ending with the letter "S").

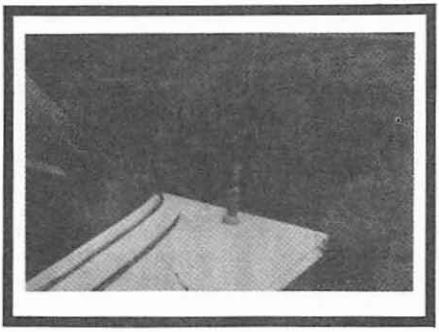
Pre-Prog: Slang term usually applied to General Electric units manufactured before the "Progress Line." Often this term is used to apply to units immediately preceding the Progress Line which are similar in appearance.

Private Line: The registered trademark for Motorola's version of CTS.

Single tone: The use of a high-pitched tone for control of remotely situated functions. This differs from CTS in that the tone lasts for only a short period of time. These circuits are often used in amateur repeater applications to restrict unauthorized use of the repeater and to reduce intermodulation effects.

Progress Line: A General Electric trademark for its pretransistor line of units. These units normally have vibrator power supplies. Newer types, with transistorized power supplies, are called "TPL."

TPL (Transistorized Progress Line): A trademark of General Electric used for their line of equipment utilizing transistorized receivers and tube type transmitters. The rear mount versions of this unit have the



majority of the receiving circuitry located in the control head.

Twin V: A registered trademark of Motorola originally applied to mobile units capable of operation from 6 or 12V sources.

Warp: The pulling of the operating frequency by either inductance or capacitance changes being introduced in the oscillator or i-f circuit. This technique is also called "rubbering."

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Getting Started in VHF

Great strides in VHF achievements have been made over the years on every VHF band that exist (when we refer to VHF, this includes 220 mc and 432 etc.). However there still remain vast segments in the VHF frequencies where there is virtually no activity. Some amateurs and organizations have prognosticated that the FCC won't be long or very reluctant in claiming back portions of the current VHF frequencies, generously allocated to us amateurs. This interpreted into another manner means that if we are to retain current VHF frequencies and the privileges that go along with them, we must all help spark more interest in VHF work and if possible, contemplate VHF setups for ourselves, preferrably on 2 or 6 meters and both if possible.

You've probably come across half a dozen or so advertisements highlighting the newest and most recent VHF equipment on the market. And while perhaps not as attractive as a nice low band kilowatt transceiver, you're probably much intrigued as to just what these VHF rigs can do. If you've never been on VHF before, I suggest you start off with a low cost transceiver for say $50.00 or so. Heath company currently offers the "lunch box series" of either a 2 meter transceiver (HW-30) or the 6 meter version (HW-29A). Both units are identical in physical appearance and structure and each sells for $44.95 apiece kit price complete with built in ac power supply and a ceramic microphone. Crystals and a dc power supply are optional. Assembling either unit is simplicity in itself and as a rule, can be completed in a few evenings of consistent work. Transmitter power input is 5 watts and the receiver is of regenerative type. The current ham publications occasionally offer modification plans for these two transceivers in case you'd like to improve upon its performance.

Going up the price ladder you'll find several 2 and 6 meter transceivers manufactured by both Lafayette and Allied with an average power input of 20 watts. Receiver is of superhet type and built in VFO is also among the features. Other manufacturers include Clegg Laboratories, Gonset, Johnson in addition to several others. A brief letter requesting their catalog of VHF gear should do the trick and is your first step in becoming familiar with what's on the scene.

What about antennas? Among the numerous VHF antennas are yagis, ground planes, Halos dipoles, collinears, verticals in addition to others. VHF antennas in the majority of cases are much smaller than HF antennas, but the dozens of methods you can use in stacking beams, adding reflectors, experimenting with them, building and designing them, etc., makes VHF antennas a field by itself. Some VHF'ers stack up to five beams one on top of another resulting in a directive gain of over 50 db and sometimes more. Others like to homebrew and construct their own antennas sometimes putting up to 50 elements on one boom! Obviously, VHF antennas offer a unique opportunity to build your own skywires and simultaneously learn more about antenna construction and theory. The complexity to which VHF antennas may grow is startling. Some of the more advanced and sophisticated antennas used often for moonbouncing, microwave and several other uses are parabolic dishes, helical antennas, screen reflectors and corner reflectors. Some amateurs may stack half a dozen collinear antennas to form an array of enormous gain while others employ perhaps one screen reflector to equal that of the array of collinears. The amount of gain you want and the purpose for its need most often prescribes what kind of VHF antenna installation would be feasible.

Starting off with a commercially built halo antenna will give you adequate local coverage if you have a fairly good location and when hooked up to a low power 2 or 6 meter transceiver, will often provide reliable coverage and makes a dandy little outfit for ragchewing and net coverage. Extending your range using the same low power rig can be accomplished by installing a moderate 2 or 6 meter beam. Seven element 2 meter beams can be had for between $10-$25 depending upon the type and brand. 6 meter beams

with three to four elements sell for $15-$30. Installing a yagi beam is no more difficult than installing a good size TV antenna. Attention should be given to the use of a balun; however, an item often neglected by many VHF'ers. Use of a rotator is an absolute must if you do intend to use a beam antenna. The many disadvantages of using a beam without a rotator is obvious since the beam will transmit in only one direction and when in net operation with hams in all directions, you'd be lost. Same applies to roundtables with hams in different directions. 50 ohm coax is the feedline used in the vast majority of VHF rigs and its losses, though somewhat higher than those of 300 ohm twinlead and open-wire line, are for the time being unimportant.

Range? Normal ground wave transmission on 2 and 6 meters with a power usage of 5-20 watts will as a rule exceed 20 miles and go as far as 45-50 using an omni-directional antenna of appreciable height. Using a beam will extend the range up to 60-70 miles and an occasional 100 mile contact isn't by any means rare. Making use of the ionosphere will of course stretch your signal for a long distance. Tropospheric bending is the most frequently encountered form of DX and 150-200 miles most often prevails in this case, though greater distances have been reached. F2 layer DX occurs at peak years of the 11 year sunspot cycle, and produce ranges nearing 2000 miles. F2 layer DX works well on 50 MHz operation only. Sporadic E layer DX is another frequent ionospheric occurence and normally will produce 400-700 miles or so on 50 MHz and up to 1400 miles on 144 MHz operation. Meteor scatter and moonbounce, among others, are all effective means of obtaining great distances with relatively low power equipment.

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Operating Practices

When you operate, what do you want in a system? You may say reliability, quality of equipment, as well as ease of operation. Perhaps you have as insatiable thirst to tinker with equipment to get the absolute best performance. VHF-FM can satisfy all these requirements and more.

As you may know, VHF-FM is growing faster than any other mode. Why has such a relatively new concept enjoyed such popularity? Perhaps we can answer this by asking still another question. What is VHF-FM? Of course, you could say that you FM a VHF transmitter. But VHF-FM (or just "FM" from now on) is also an entirely different system of communications.

About 75% of all FM activity is operated from the mobile. The rigs are surplus gear taken out of commercial service (taxis, police cars, fire trucks, etc.). When you purchase these rigs, they come with all accessories . . . transmitter, receiver, power supply, mike, speaker, control head and cables, but less crystals and antenna. They seldom run over 60 watts, with most rigs running 30 watts or under. Antenna polarization is always vertical. FM deviation is usually wide-band (±15 khz) but there are a few scattered narrow-band outfits (±5 khz). The trend today is toward narrow-band operation, though. You can get a complete rig for as little as $25, but the usual price runs between $40 and $90 when obtained from a dealer. The possibility of obtaining the used equipment directly from the commercial user should not be overlooked.

As noted, just about all FM activity is crystal controlled and hence, operates on "channels." Because of accepted channels, repeater stations can be utilized. Such repeater stations, usually located on high ground with higher power, receive signals on one frequency and simultaneously retransmit the received signal on a different frequency. Going through a repeater, you can cover a 50 mile radius using just a one watt walkie-talkie. However, in speaking with other hams, I find that there is one big misconception about FM. It seems that quite a few people think that you *must* go through a repeater. Quite to the contrary. As a matter of fact, in southeastern New York, most FM activity is "direct," without the aid of a repeater.

Another advantage of channelizing is that most stations can, and do monitor. When an FM'er gets out of work, on goes the mobile rig. When he gets home, on goes the base station. After a while, you know when the different stations are monitoring. You are now approaching the reliability of the land-line via ham radio.

Emergency communications is one of FM's strongest points. The fact that all stations are always on frequency and FM receivers are not susceptible to lightning or ignition noise provides for an extremely reliable situation. With some repeaters, if the commercial power fails, an emergency generator automatically kicks in. The abundance of mobile and portable equipment as well as the fact that much of this was designed originally for emergency use, gives FM the upper hand in most any emergency.

Operating procedure on channelized FM is somewhat unique. In some parts of the country, the commercial "10-code" is used. This does provide for quicker QSO's, but this aspect of operation has *not* been used to any extent in the New York City area as well as many others. "CQ" is *never* heard on FM, since there is just no need for it. All stations are on frequency, so no long call is needed.

You might simply say, "This is WB2AEB monitoring nine-four," and that's it. If anybody wants to gab, they'll answer. Since the channels are well known, when referring to them you simply say the numbers to the right of the decimal point. Thus when you refer to 146.94 mhz you say "nine-four."

When referring to 52.525 mhz you say "five-two-five."

Even where six-meters AM may reign king, two-meters is often where the FM ham stays. On a national scale, two-meters is also the most popular channelized FM band. 146.94 is the national two-meter frequency with other side channels such as 146.76. The national 6-meter frequency is 52.525 mhz. There is also a national ten-meter frequency and this is 29.6 mhz. There are about 300 hams on this frequency and more are joining every day. This band is popular because the skip comes in more often than the VHF bands. To get on ten-meters FM, you simply tune the rig down to 29.6 mhz instead of 52.525 mhz. The low-band rigs tune from 25 to 50 mhz often with few modifications.

As for UHF, the ¾ meter band is popular for your own "secret" repeater. To the FM'er, six-meters is called "low-band," two-meters is called "high-band," while the ¾ meter band is called "450" or simply "UHF."

Mobile Installations

As stated earlier, 75% of all FM activity is operated from the mobile. Fortunately, mobile equipment is easiest to come by and is less expensive than a base station. Again, when you purchase these units, they come with all accessories–transmitter, receiver, power supply, control head, speaker, mike and cables.

Most two-meter rigs have to be converted from the adjacent 150-174 mhz Business Band down to the high end of 146 mhz. All this involves is maybe padding each of the receiver "front end" rf coils with a capacitor of good quality and possibly making a new final tank coil. As for 6-meters, the units have to be brought up from the 30-50 mhz Business Band to above 52 mhz. Depending upon where the rig was previously tuned, you may have to cut down some coils or perhaps change a few capacitors. The rigs that are to be put on "450" often need no modifications. In every case, however, the rig must be completely re-aligned and new crystals must be installed (more on this subject later). Converting narrow-band gear to wide or wide-band to narrow does get a bit more involved. The rigs are usually slightly scratched up and dusty (depending on age). However, some sandpaper and a can of spray paint can really do wonders. Any way you look at it, the rig itself will be in the trunk and the only things that you can see are the control head, mike, and speaker under the dash.

As for mobile power supplies, they come in three types: dynamotor, vibrator, and T-power* (transistorized). The dynamotor supplies are always found in the rigs from the 1952 to 1957 era, usually running to 60 watts. These dynamotors do waste a ferocious amount of power as compared with a vibrator. The price of the unit is less however. Vibrators provide a good compromise. They do not eat up as much power as a dynamotor and are not as expensive as a T-power rig. Vibrator supplies were most prevalent between 1952 and 1962. If you want to pay for the best, you can get T-power, but quite a few hams who want this feature modify the existing rig. The advantage of T-power is that it is the most efficient method and it lasts the longest. T-power rigs can be found from 1962 to date. The oldest rigs use 6 vdc only, with later rigs using 6 *or* 12 vdc and even later ones using 6 *and* 12 vdc. The newest rigs (still in production) tend to use 12 vdc only.

In receivers, the sensitivity is usually quite good–on the order of 1 μv to 0.5 μv for 20 db quieting without a preamp. If your particular receiver does not match this, a simple FET pre-amp will fix things up in a jiffy. Receivers such as the Motorola Sensicon "A" also have a "cavity front end."

With transmitters, the power rating is in *output* rather than *input*. Thus, you can compare a 60 watt commercial FM rig with a 120 watt amateur transmitter with 50% efficiency when measured for input. The moral is, don't let the 10 watt power rating on some of the cheaper rigs scare you away (i.e. Motorola FMTRU-41V $35 up). By the way, many of these rigs are not really FM, but Phase Modulation. These two methods are received alike in the FM receiver, though.

As for makes of rigs, Motorola and G. E. are the two big names. For the beginner, perhaps these two are the best to start with because schematics and documentation are easy to come by. One more school of

*Reg. trademark of Motorola.

thought is that since these brands are the most popular, if you run into trouble, you can easily consult someone with a similar rig on your problem.

Mounting these rigs is somewhat unique. You have a choice of two methods. First, you can mount the whole rig under the dash. Second, you can mount the rig itself in the trunk with the supplied cables leading to the control head, speaker and mike under the dash. This way, the chance of theft is less, and the XYL gets her leg room. The latter is more popular and the price is usually the same.

If the rig was built before 1952, the chances are that the transmitter and receiver are separate cases. From then on, however, the transmitter and receiver are in the same case, but in modular form. Thus, if a unit went bad, the service technician would simply plug in a new transmitter, receiver, or power supply "strip" and repair the old one.

Where do we obtain such equipment? Of course, if you want to get the best price, one of the "Hams Only" distributors is ideal. However, if you want a large selection, a commercial distributor is for you. With some companies, some equipment is sold as-is, but most companies have a short guarantee. Before you do anything, however, you had better write for a few catalogs to determine what you would expect to pay and become familiar with some of the rigs.

Here are a few such companies with catalogs:

Gregory Electronics Corp.
249 Rt. 46
Saddle Brook NJ 07662

Mann Communications
18669 Ventura Blvd. Tarzana CA 91356

Spectronics, Inc. (Hams Only)
1009 Garfield Street
Oak Park IL 60304

C & A Electronic Enterprises
2529 Carson Street
Long Beach CA 90810

Although this company does not publish a catalog, Newsome Electronics is a "Hams Only" distributor with competitive prices.

When buying antennas for the mobile rig, it may be good to get what is called a "gain antenna." The familiar gutter clamp type antenna which is popular in some temporary installations (which figures out to be about 18.7 inches) let's say has a gain of "X." With the use of a "gain" antenna you have a 3 db gain over the 18.7" whip. Thus you can get 2X gain with the use of the "gain" antenna. Think about that . . . twice the power out (ERP) and twice the receiver gain just by using a different whip. You can get a small 18.7" antenna (commercially built) for about $6. A "gain" antenna will run anywhere from $16 to $27.

Now about one of the most important topics . . . prices. Prices will all vary according to age and condition of unit, transmitter power, type of power supply, manufacturer, and whether the unit is narrow-band or wide-band. Commercial dealers will always want more for narrow-band gear. Just because you paid twice the amount of an older unit for your later model, don't expect the newer one to be twice as good. The older unit may be dirtier and take up more power, but that's about it.

Hand Held Portables

The abundance of portables is one of the strongest points for FM. In time of emergency, you need not be connected with commercial power in any way, thus giving operation in the most extreme conditions. If you have access to a repeater, one unit could be your portable, mobile, and base station. If the repeater is out of commission during the emergency, you had better be able to go "direct" for maximum reliability.

The usual FM portable is quite different from the usual 100 mw 11 meter rig. When a C.B. walkie-talkie weighs, say 16 oz., a common FM portable may weigh over 16 lbs. (yes, lbs.). As for power, FM portables seldom run under one-watt or over five-watts output. The rigs are either in packset form (hand-held unit at waist level with external mike) or if you've got the money, a single hand-held unit like the 27 mhz type. Power is often supplied by Nickel-Cadmium (ni–cad) batteries. The price of the unit itself is brought up with ni-cads over dry batteries, but the savings in buying new batteries overcomes this.

The care of ni-cads is an art in itself. One can easily ruin one of these batteries. Before

you even turn the unit on for the first time, you should become very familiar with ni-cads with regards to charging, discharging, and storage. With used ni-cads running up to $15 and new batteries going for around $65, you can't afford to destroy them! You do not have to use ni-cads with many of these rigs, however. You can use Mercury, Alkaline, and the common Carbon-Zinc battery, but they just do not respond to charging and over-all life as well as the ni-cad. With proper care, the ni-cad should last indefinately.

In general about packsets—these can also come with telephone-type hand sets as well as the standard external mike and internal speaker. Also, when planning to purchase any recent vintage portable, you can count on getting one with a narrow-band receiver. With transmitters, you can usually select wide or narrow-band operation by merely adjusting the deviation pot, while receivers will require a fair amount of conversion.

Following are descriptions of just a few of the more popular portables. Since 2 meters is where most FM is, we will discuss high-band gear. In most cases, however, there is a 6 meter rig with fairly similar specs. **MOTOROLA FPTRU-1 AND FHTRU-1**: These are two old "war horses" which are entirely made of modular tube construction. If unconverted, these should be avoided unless you have plenty of time. Due to their age, these are sometimes in poor condition. **MOTOROLA P-33**: Production was stopped around 1965. These have quick heating tubes in the transmitter. Some have a partly transistorized receiver (P-33 AAM) while others have an entirely transistorized receiver (P-33 BAM). Receiver sensitivity is 1μv and 0.35 μv with an FET pre-amp. One side note... to install an FET pre-amp in this unit all you need is a 3N128. You put this FET between two tuned front-end stages already in the unit and that's it. . .no additional components needed! (thanks to W1RYL for this information). Power output is 5 watts with a 2E24 in the final. Power can come from ni-cads, dry batteries, your car's 12 vdc ignition system or other external source. When not running on internal batteries, be sure that the unit is getting exactly 12 vdc. The transmitter has three 6397's as the driver (look up the price on one of these some time) and it has been found, the hard way, that these will blow if the power supply is not giving the correct potential. The weight of the unit with ni-cads is 18 lbs. Electrically, the P-33 can compare with a Gonset Communicator I, II, or III as well as other 2 meter transceivers. You can get a P-33 BAM for about $80 less ni-cads and as-is. Ready-to-go units go for around $140. **MOTOROLA H-23**: same as P-33, but one-watt and 12 lbs. with ni-cads. Price : about $65 less ni-cads and as is; $125 ready-to-go. **MOTOROLA H-23 DEN (DCN) or HT-200**: These rigs are the same units, but the names are different. The HT-200, as it is now called by Motorola, can come with 1.4 or 2 watts, remote speaker and mike, and Private Line (continuous tone squelch). If you wish, the antenna can be built into the mike cable! Receiver sensitivity is 0.5 μv, with the weight of the unit varying between 32 and 38 oz. This unit can also come in a 450 mhz version for use in a "down-link, up-link" repeater set-up. The entire unit is hand-held like a CB rig with the size varying between the size of 3 to 4 packs of cigarettes. Needless to say this unit is in great demand. You might obtain a used unit for about $200. **MOTOROLA PT-200**: This unit is a new breed of P-33's which can come in either 2 or 5 watts. The transistorized unit has a receiver sensitivity of 0.2 μf with an FET. Weight: just 5 lbs. If you can find a source, the price used is about $225. **G.E. VOICE COMMANDER SERIES**: These are quite popular because they are light weight, small and are not as expensive as one might imagine. They weigh roughly 5 lbs., and are about the size of the Handbook. One watt out is about what to expect for power. The Voice Commanders can be used with dry batteries or ni-cads, with ni-cad chargers going for about $10. Receiver sensitivity is about 0.35 μv with a pre-amp. There are three types of Voice Commanders: **VOICE COMMANDER I**: This version has tubes in the final but the rest of the unit is transistorized. The speaker and mike are built into the case so you have to talk right into the unit. The standard supplier will want about $75 for this unit with ni-cads. **VOICE COMMANDER II**: This unit is fully transistorized, but you still have to talk into the rather large case using two hands. The price is about $100. **VOICE COMMANDER III**: This unit is fully transistorized like the above, but it has a provision for an external PTT mike and speaker. The Voice

Commander III very often comes with a built in pre-amp. This version is hard to find as surplus. With the new unit going for about $700, $175 is about what to expect used with ni-cads.

...WB2AEB

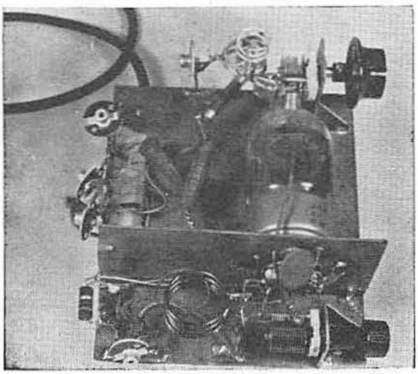
The Sixer Linear

A persistent topic of typical VHF rag-chewers today concerns the absence of good low-cost rigs in the 50 to 75 watt class for the developing VHF amateur of the do-it-yourself type. These are for the young lads who save pennies, not dollars, until they get enough to send away for a Sixer, (personally I hope they send for a Two'er, since that's my favorite band) or maybe a used Gonset for six meters. They would like quite a bit more power if they could afford it. Several things get in the way though. First, what to buy, or build.

What to Build

Here there are all kinds of choices, generally leading into high voltage, an expensive modulation transformer, and what final? Well, to put your mind at rest right now, there is a tube selling for $1.75 that can do the job practically all by itself, without a modulation transformer and with a reasonable HV supply of some 300 to 400 volts. This is the 815 Beam Power Double-Pentode run as an AM linear. It is a "surplus tube." It is a well tried design and one I used on 5 and 2½ meters before World War II, to be strictly honest. What happened to it? WW 2 came hurrying along, driven by the mad paper-hanger, and the 832 and the 829 were rushed into being and served well in the Armed Forces.

The 815, with its slightly reduced rating at 144 mc, took a back seat and apparently has



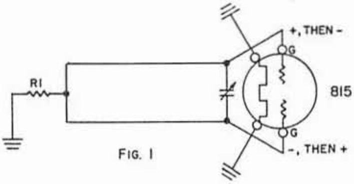


FIG. 1

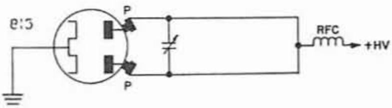


FIG. 2

stayed there. However, it still is *not* listed as "For renewal purposes only" or "discontinued type." Briefly, it is listed at 25 watts dissipation and will put out a good 25 watts also, cool. Being a double tube with parallel dc operation, it does this with voltages (300-400) that can be obtained from a power transformer from almost any old Tee Vee box.

The 815 is one of the first, successful Twin Beam Power tubes. The heater is either 6 or 12 volts, which is handy for mobile. It has an octal socket which is good because low cost, and because the plates are on the *other end* of the tube with two plate caps.

The 815 is somewhat like two good 6L6's in one envelope with plate connectors on top, common screen, common cathodes, with the suppressors internally connected to the cathodes. It has always been a good low voltage high current rf tube. The beam power is a name, and a good one for the use of grid and screen wires so lined up that most of the electrons reach the plate, and do not hit the screen on their way over. This is particularly useful just at the time it is needed most. That is, when developing power the plate should swing way down near zero. At that time the plate is more negative than the screen and electrons would tend to be more attracted by the screen were it not for the beam effect.

The formation of a "space-charge" helps too. This little electronic trick is a concentration of electrons near the plate, which being negative,

(the concentration, that is) tends to repel secondary electrons from leaving the plate. If electrons left the plate it would go positive just at the time you want it to go negative. These nuisance secondary electrons are the result of the primary electrons, the ones you get from the cathode and want to use, going "Hot-Rod," at some 67 million miles per hour, and hitting the plate at that speed, which causes "electron splatter". Of course, you *want* them to reach the plate but you don't want the secondaries to leave the plate. When as many secondaries are leaving the plate as primaries are arriving, you don't produce much power!

There is a much more complicated and important deal that enters the picture too, even more so at UHF, but we will look deeper into that later on. This is the very great difference between the flow of electrons in a tube, at some fraction, say one twentieth, the speed of light for a plate voltage in the few hundreds, and the flow, or rather progress, or speed, of the electromagnetic *wave* along the plate strap, line, or cavity wall, which is practically at the speed of light.

So now we have the electrons at the plates of the 815, first on one plate then on the other, as the tube runs best in push-pull, and it really develops power. As mentioned, a good 25 watts output at 144 mc, or on 50 mc in this case.

Fig. 1 shows a big advantage of push-pull action at VHF. With a single grid the rf must be applied between grid and cathode. With push-pull the rf is applied to the two symmetrical grids, so that automatically there is a large and properly phased

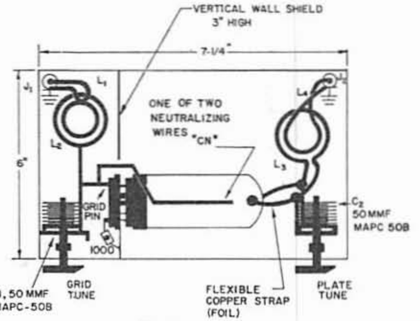


FIG. 4

L1 6 T #18, 5/8" long, 5/8" O.D.
L2 5 T #22, covered, 1/2" long, 1/2" O.D.
L3 2T #22, covered, closewound, 1/2" O.D.
L4 3T #22, covered, closewound, 3/8" O.D.
L5 3T air wound, 16 per inch, 1/2"
L6 4T #14, 5/8" long, 5/8" O.D.
Ln 4T #22 plastic covered, 3/8" O.D., 1/2" long inside L6
L7 2T #18 covered, 3/8" O.D., adjustable coupling to L6

voltage between each grid and the cathode. The same effect applies to the plates, only more so, and a little different. As you can see in Fig. 2, electrons will arrive first at one plate then at the other. The electromagnetic wave, which is the type of energy you are interested in getting into the antenna and over to the other fellows antenna, travels back and forth on the U shaped inductance and does *not* have to be bypassed back to the cathode, as you can see.

Briefly, and exaggerating a little, for a 500 volt HV supply, first one plate gets a glop of electrons from the cathode as its grid goes toward positive. These negative charges cause the plate to drop near zero, providing of course that everything is working right, and also remembering that it takes a certain number of rf swings to reach the point of operation. The next instant (rf-wise) the electrons stop arriving at that plate and it "bounces" back positive again. It does not necessarily stop at 500 volts though, but may go much higher. In fact, you can get an interesting purple arc across the tank capacitor with no loading! Same action at the other plate, but of course a ½ cycle later. Fig. 2 shows plainly the "turning fork" or resonance effect that takes place between each plate and that there is no bypass needed back to the cathode. There is of course a steady average potential difference of 500 volts between both plates and the cathode. Remember though that this is only an average, or dc difference. At one moment, rf-wise, it may be zero, the next moment 1,000 volts difference.

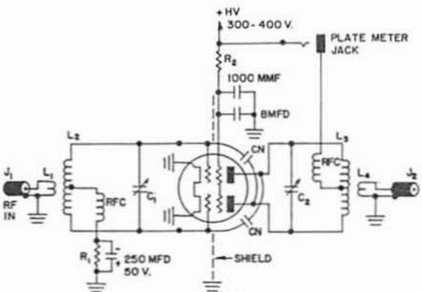
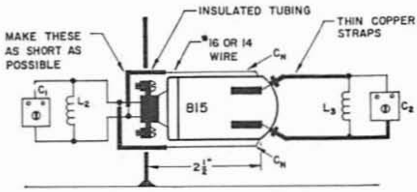


FIG. 3

L1 3 T interleaved near middle
L2 4 T heavy copper wire, #12 at least, 3/4" long 1 1/4" O.D.
L3 6 T #14. 1 1/4" long, 3/4" O.D.
L4 3 T #18, interleaved, 1/2" long, 1/2" O.D.
C1 & C2 50 mmfd Hammarlund MAPC-50B
Cn See text
R1 5K
R2 20K, 5W



NOTES:
1. CAPACITOR MOUNTING STRIP NOT SHOWN.
2. C_1, C_2, SEE TEXT.

FIG. 5

So, enough on push-pull. It works. You can use coils of course instead of straps.

Time was, on 5 meters "long-line" plate tanks were quite the thing. You went to someone's shack and there up on the wall or stretched out on a table were some three feet or so of double copper tubing, side by side, as in Fig. 2. You can also wind up the copper strap into coils.

The Circuit and Tune-up

Fig. 3 shows the complete circuit. It is quite simple really and similar to class C amplifiers you find in the books. Except it doesn't need a modulator. While grid circuit "swamping resistors" are recommended for SSB linears, we could find no advantage here in the AM linear. Not only that, but remember that the Sixer does not have unlimited rf power output.

The 815 is mounted horizontally on a vertical wall of copper-clad bakelite. Fig. 4 is a bird's eye view of the assembly. Fig. 5 is a front view of same, and Fig. 6 shows a pictorial of the 815 socket wiring.

Providing you use a good shield-wall to mount the socket on, and follow the simple neutralizing instructions, you can probably use a more compact assembly, or a different one, to suit your construction needs.

In Fig. 5 the grid and plate tuning capacitors are shown without mounts, I used the same bakelite again, soldered to the base plate, shown in Fig. 5, for mounting brackets. Of course, if you want to use heavier non copper clad bakelite with metal angles, nuts, and bolts, go ahead. In any case, use insulated shaft extensions.

In Fig. 5 ordinary capacitors were used instead of symmetrical butterfly ones! It still works, but be sure and use butterfly capacitors and you will get a better balance in the L2 and L3 circuits. Hammarlund BFC-50's are recommended.

Fig. 5 also shows the neutralizing circuit. This is important but not critical, so don't worry about it. It acts very clean and neat. With the complete set up as in Fig. 3, apply filament voltage but no screen or plate voltage. Then, with rf drive from the Sixer or other driver applied to J1, some 15 to 20 volts should develop across R1. A diode detector tuned to 6 meters should be plugged into J2. Do *not*, turn on the plate and screen voltage of the 815 unless you own a *lot* of diodes!

Some rf should show in the detector, unless you just happened to have neutralized the 815 on wiring to the dimensions shown by good luck. Fig. 6 shows exactly 2¼ inches of wire for the cross-over neutralizing "capacitors." The way we did it was to make them a little longer and then trim them down near the right length. Then, watching the diode meter for the neutralizing null, which will be very evident, trim the wires for that null. You can bend them a little, leaving the wire tip pressed against the tube glass for rigidity. Once done you can leave them years.

Further checks can be used, although of a less precise nature. First, tune the plate circuit through resonance, without plate or screen voltage, and watch for absence of reaction on the grid circuit. A voltmeter across R1 will show movement if the tube is not neutralized. The above is with rf drive from the exciter. Then cut off the rf input drive, apply plate and screen voltage and tune C1 and C2 over their ranges. No self-oscillation should occur. It is assumed that everything is in good working order, that the grid and plate circuits tune well above and well below the 50 mc band. Actually these tests above are *final* ones. The whole process should be repeated several times in order to be sure that everything *is* in good shape.

815

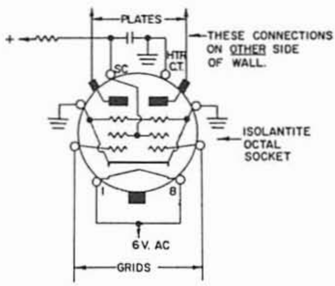


FIG. 6

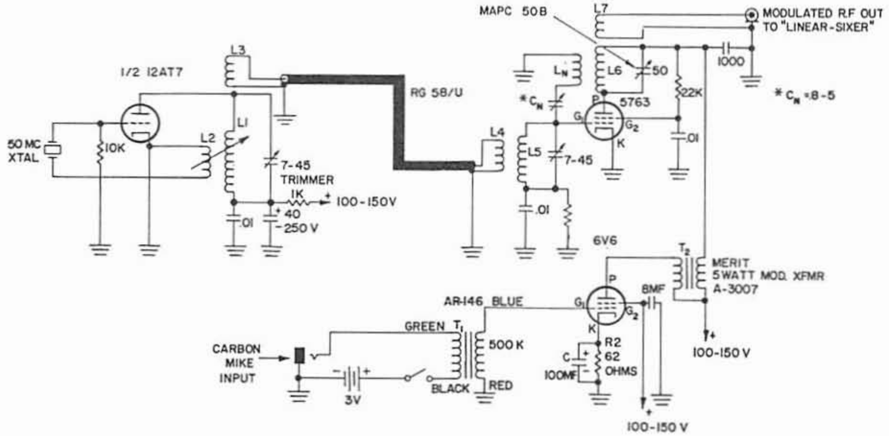


FIG. 7
Driver modulator for linear

Linear Tune-up

The rig should work OK if you make it up as shown. However, I advise you to check with a 25 watt bulb as a dummy load first. With between ½ watt and a watt input, you should get 20 to 25 watts output, using 350 to 450 volts and 100 to 150 mils on the plates. Be sure and *overload* the plate coupling! Linears like that! Without load you should get a good 50% plate dip in current, and good fat smoky sparks with a pencil (wood!) on the plates.

Listening with the diode, transistor amplifier, and padded earphones, you *should* hear the kind of modulation you like to hear. Overdrive the grid circuit and see if you can make it distort. It *should* when you go up much over a watt on the driver output. You then reduce it back to where it sounds good. Your Sixer may not be able to drive it that hard. You will easily find the input level that should not be exceeded. Incidently, though not surprisingly, the drive can be increased if more plate and screen voltages are applied to the linear. You can go up to 500 volts if you really insist. Just watch those plates for color! I could not see any color at 60 watts input. With 25 to 30 watts output without modulation, and more with modulation.

. . . K1CLL

Six-Meter "½ Gal."

This final vf will put *out* nearly 400 watts on CW or FM telephony (or a good quarter kilowatt *out* on AM phone). In case you or your buddy haven't a pair of 811As lying around, you can buy them new for only $7.75 each. With only two of these tubes, a couple of two-gang balanced capacitors, a few knobs and jacks, and you're on the air. And it can't cost you over $25. For the amplifier, that is. Of course, if you don't have a husky power supply lying around the costs will start to mount a little.

The Main Idea

Filling a "one-of-a-kind" contract recently involving construction of a "radio frequency power supply" which called for 5 kV (yes, five thousand volts) at 70 MHz to be used in ionization work, several things came to my mind for amateur homebrew work. Ruggedness, simplicity, smooth tuning, and low cost were among these thoughts.

A lot of fine tubes have come out since the 811As appeared some 25 years ago; but which among them will give you nearly 400 watts of FM output for $15 a pair, *new*? Also, without screen voltage, bias, blower, or screen modulation?

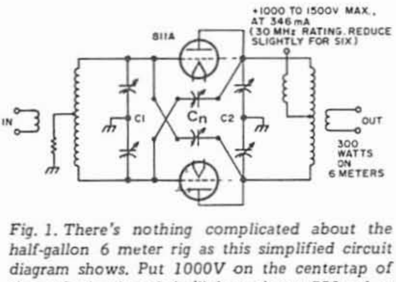
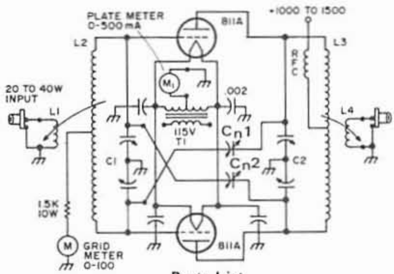


Fig. 1. There's nothing complicated about the half-gallon 6 meter rig as this simplified circuit diagram shows. Put 1000V on the centertap of the tank circuit and she'll draw almost 350 mA at resonance.



Parts List

C1, C2	Bud 1557, spaced 3/32 in.
Cn	Bud, 6-plate (≈10 pF)
T1	6V CT at 10A
C3, C4, C5, C6	.002, 1 kV
L1	1 or 2 turns coupled into L2
L2	6 turns (14 AWG), ¾ in. O.D.
L3	1/8 in. copper tube, 1½ in. O.D., 6 turns
L4	1 or 2 turns link (10 or 12 AWG)

Fig. 2. This complete schematic shows all the details for constructing the final, and gives the information necessary to include proper metering.

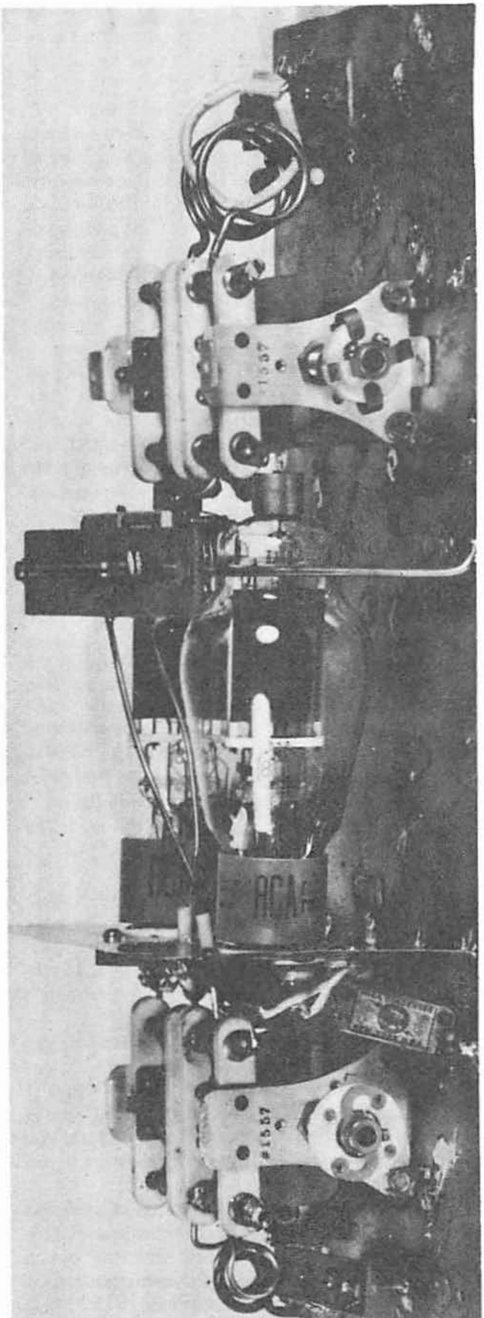
The Circuit

Figure 1 shows how standard and simplified the circuit is. Just take a few precautions as noted here, and refer to Fig. 2 for details. One of the advantages of push-pull circuitry concerns the almost complete absence of bypassing requirements (just C3, 4, 5, and 6 on the filament leads). You can bypass the grid and plate return but if L2 and L3 are really centertapped there will be no rf on those leads anyway.

Be sure to keep your fingers away when operating. Remember, they only use 1900V even at Sing Sing!

Neutralization

These 811A tubes are "old-fashioned" triodes but a lot of circuits show them in the latest handbooks. They do require proper neutralization to work good as trouble-free amplifiers at 50 MHz – not critical though, just the proper kind. Since



these are "zero-bias" tubes, you can apply 500 to 1000 volts on the plates with no external bias needed and, if not yet neutralized, and L2 and L3 are anywhere near in tune, they will take off and oscillate in great style with several hundred milliamps on the plate meter. This you *don't* want; so, using considerable care and a long, insulated handle, vary neutralizing capacitors C_n1 and C_n2 so that no oscillations occur when L2 and L3 are resonated back and forth across the band. The proper neutralizing capacity is not hard to find, but be sure and rock C1 and C2 *all* over the 6 meter band while adjusting the C_n capacitors. The grid-to-plate capacitance C_{gp} for the 811A is listed as 5.4 pF. We used high-voltage 10 pF capacitors, variable – and sure enough, the dial knobs (which are handy for logging the correct spot for neutralization) ended up near the middle of these scales. Once neutralized, the rig can tune all over the 6 meter band so smooth it seems like magic.

Layout

Being a fanatic about copper-clad Bakelite (or fiber glass if you're fussy), for baseboard use in experimental work with transistors, I tried one here and the results were equally good. The photo shows the layout used, which works fine, either by itself or bolted on a chassis when finished and in a cabinet with dials, input and output jacks, etc. Be sure and use short copper leads for all the rf connectors – especially for the neutralizing circuits and plate tuning components C2 and L3.

Actually, with push-pull circuitry you hardly need a metallic baseboard, but it does allow for easy construction and grounding. And when finished you can bolt

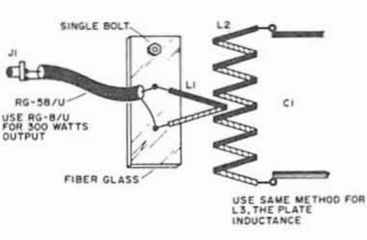


Fig. 3. An effective semifixed link coupling method can be obtained with the link mounted on a pivotable piece of fiber glass.

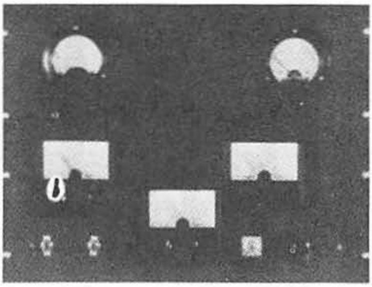


Fig. 4. This photo shows how a complete high-powered transmitter can be obtained using the simple two-triode final.

it down onto a chassis without change in its operation.

The two flexible couplings on the variable capacitor shafts can be seen in the lead photo. These allow easy placement of the shafts into the back of the Millen dials and take any strain out of misalignment.

Filament Leads

I used 10-gage here because I like plenty of voltage on the filaments. Be sure to mount T1, which should have at least a 10A current rating, as close as possible to the sockets. Each 811A draws 4A, which is one of the reasons they work so well. There is nothing like plenty of electron emission for action! You can even light a 20W bulb at J2 just from electrons going over to the plate through the grid with the B+ lead *open!* You'll also find up to −400V at that point, due to those same electrons landing there.

When you do apply the regular dc plate voltage of some 1000 to 1200V a 200W bulb should light up at J2, but good.

Link Coupling

As usual, with good tuned circuits, not much coupling is needed. One or two turns about halfway in will do the job when loaded into a good tuned-up beam antenna. Both the C1−L2 and the C2−L3 circuits handle very well, with no jumps or odd spots. You will find that overcoupling to L2 shows up with two-peak tuning. Move L1 further out of L2 and good single-peak smooth tuning will be restored. And, once again, be sure and keep your cotton-pickin' fingers off those coils. We don't like to lose readers.

Semifixed coupling links can be used, as shown in Fig. 3. The two terminals can be mounted on a movable piece of linen-based or fiber glass insulating sheet, and fastened with a single bolt to the baseboard for easy adjustment in and out of tuned circuits L2 and L3.

The photo shows two bolts for mounting L1 and L4. Suit yourself on that. L4 should use fiber glass insulating tubing, or air spacing. Don't forget there's plenty of fire in L3! Adjust rf output link L4 for a slight dip in plate current at resonance, which should coincide with maximum rf output. If you apply the old-fashioned pencil test to L3 when unloaded, be sure to fasten the pencil to a long wooden handle first. You're dealing with over half a horsepower there! The photo of Fig. 4 shows the front panel used on my job. The three Millen dials are used for logging purposes; two of them tune the grid and plate, and the third is for the 70 to 80 MHz oscillator (which, of course, is unnecessary for a straight rf amplifier as described).

Power Supply

Inasmuch as the 811As are 25 years old, I had to dig way back into the cellar to come up with a collection of power transformers, chokes, 866 rectifiers, etc. dating from my 2 meter kilowatt days in the 1946 – 1949 era. Most of these items have *increased* in value during this time, and they still did a very good job in delivering some 400 watts for the 811As. All you need, basically, is the type 21 Powerstat knob and two toggle switches on the front panel, as shown in the photo of Fig. 5. The Powerstat controls the 0−1.2 kV of the high voltage supply.

If you need to build such a high voltage supply you will have to dig quite a bit through handbooks and mail order catalogs. RCA's invaluable "Transistor, Thyristor, and Diode Manual" is the best help I found.

In the bridge rectifier department, the RCA manual has the "direct replacement for 866 rectifier tubes" in the CR 275 stack, and going back to the Allied catalog you can find its price, which is $22. Or you can string your own diodes together if you want some savings here.

There is a lot of talk in some handbooks about "TV replacement transformers" for use in HV supplies and with the silicon rectifier stack in mind I spent quite a bit more time browsing through the catalogs, again with only medium results. Prices for

more time browsing through the catalogs, again with only medium results. Prices for anything approaching 500W run from a low of $18 to up around $50 for transformers that will give 1500V at 400 to 500 mA.

The New Look In Power Supplies

This trend seems to me a mixture of striving for less weight, size, and cost, and at the same time trying to keep "within reason" on the side of reliability and safety. You will have to be your own judge as to the results.

For example, voltage doublers are used to get 2 kV from a 1 kV transformer and you are flatly invited to "try the transformer out and see if the center windings to core insulation breaks down" under the not-designed-for high voltage. At least you are warned! Further, six electrolytic capacitors are strung in series to make up a 2.5 kV capacitor, and the bleeder resistors are composed of the series balancing resistors used across each capacitor in this lethal device. This one can really buy the farm for you with its *10-second* discharge time! Once again, however, you are warned about it.

Modulation

The amplifier shown here can be set up for any of four modulation methods: AM, linear, FM, and SSB. There aren't any screens to worry about and the tubes are zero bias, so it's easy to plan for. Once again, suit yourself on the mode used. Oh yes, it works great on CW also.

...K1CLL ■

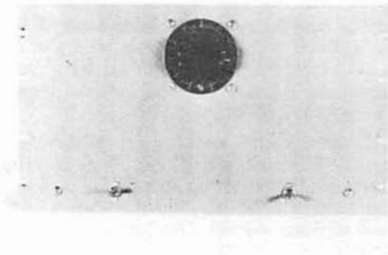


Fig. 5. A Powerstat control on the power supply for the author's rig permits variable voltage delivery from 0 to 1.2 kV.

50 Watts on 50 MHz for $50

This 50 watt station uses only two low cost tubes in the RF section including a rock-stable VFO. It ought to be rock-stable: it has a 46 megacycle rock in it! And no frequency multiplication to also multiply drift, FM, hum, etc.

The size is handy, the final being 2 inches high, by 6 wide and 5 deep, and the single tube crystal controlled VFO exciter about the same size. So, enough small talk, let's get into the main course.

It takes a little work to put 50 watts on 50 mc for $50 with a VFO rig. After all though, there are thousands of amateurs who can buy the $300 to $400 rigs, but there are also some tens of thousands who cannot! At least not yet in their careers. But anyone can afford this rock-stable 50 watt rig. Let's add it up: The exciter module comes to about $6 for the capacitors, socket, small parts, etc., if you don't have a junk box and get them all out of the catalog. Tube is $2 and crystal is $4--a total cost of $12 for a rock-stable VFO with one third watt output on 6 meters.

The rf final comes to even less. It looks like about $10 from here including the tube.

The modulator sure boosts the cost though. It costs $22 for the parts and $6 for the tubes for a total of $28. Get busy on that junk box!

So that gives us the whole rig for $50 (less power supply).

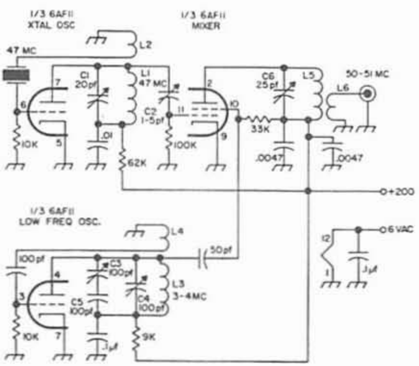


Fig. 1. Six meter heterodyne VFO exciter using one Compactron. Output is about 300 mw.

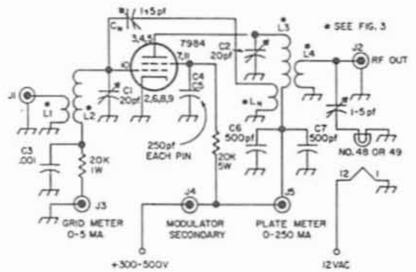


Fig. 2. 7984 Compactron final amplifier. This amplifier puts out over 50 watts with less than one-third watt drive. Note that the tube requires 12 volts on its filament.

The exciter

The exciter uses a 6AF11 Compactron tube, which has two excellent triodes for the oscillators and a high gain video pentode for the mixer, all in one little $2 bottle, definitely a bargain.

The principle of using a 46 mc crystal and then adding a 4 to 5 mc variable oscillator in a mixer is a sound one and has been around for many years. Some 90% of the frequency determination is done by the crystal oscillator. Also, any hum, FM, etc., in the 4 to 5 mc oscillator is not multiplied as in conventional VFO transmitters. The results are really worthwhile. I use ordinary 100 pf variable capacitors, copper-clad bakelite base and shielding, no voltage regulator and only one $2 tube. Also, only one crystal. For the whole exciter!

Make sure that you get the 50 mc output and not 46 mc or one of the other frequencies generated in the mixing process. Also don't overcouple the link coupled stages. This will keep down TVI.

The rf output on 50-51 mc is about 300 mw which is sufficient to drive another Compactron, the 7984, to 50 watts output! We got about 2 ma of grid drive.

The plate voltages on the three sections of the 6AF11 are: crystal oscillator, 75 volts; 4-5 mc oscillator, 180 volts, mixer, 275 volts.

The RF amplifier

The modular construction of the exciter and RF amplifier (**Fig. 2**) is quite convenient for building, tune up and final tests on the air. I find that laying the tube on its side as shown in **Fig. 3** with the 12 pin socket centered in a small vertical thin brass panel makes it easy to work on the socket and forms a module only 2 inches high by 6 inches wide by 5 inches deep. Keep the leads short—as is easy to do if you follow the layout—and ground all four cathode leads.

The neutralization system is an afterthought. Don't forget that the 7984 is a red hot beam power tube. It takes only one third watt drive from the exciter to light a 50 watt bulb to full brilliancy. Figure that gain out!

To adjust the neutralization, remove the excitation and the output coupling and put enough plate voltage on for about 100 ma plate current. Then adjust C1 and C2 for self oscillation (unless you happen to be lucky in your setting of Cn). Some setting of Cn then will give no self-oscillation. Make sure that L1 and L4 are uncoupled from L2 and L3 while you're doing this.

You can also neutralize the final amplifier by many other methods, such as no grid current dip when the plate circuit is tuned through resonance, or by looking at the RF output fed through the plate-grid capacitance with a diode detector and no plate voltage. The methods I used worked so easily that I didn't try any others and there has been no self-oscillation since.

Modulator

This is a more or less standard 30 watt modulator using two 6L6GC's as push-pull modulators. Two 6L6GC's can put out 55 watts of audio, yet cost only $2 apiece.

This modulator (**Fig. 4**) has only enough gain for use with a high output microphone such as the Astatic model 150 ($3.82) (−44 db output) that I use. This low gain helps prevent rf feedback into the transmitter and so far I've had no trouble with this normally common problem on VHF.

The modulation transformer I am using is a Stancor A-3873 rated at 25 watts maximum audio output, 8500 ohms plate to plate to a secondard load of 8000 ohms. Maximum DC is 100 ma per side. This is being stretched a little on the modulator side, but so far it's OK.

You can check the modulator with three 7 or 10 watt 110 volt bulbs in series across the modulator secondary and no rf load attached. They should light up quite brightly.

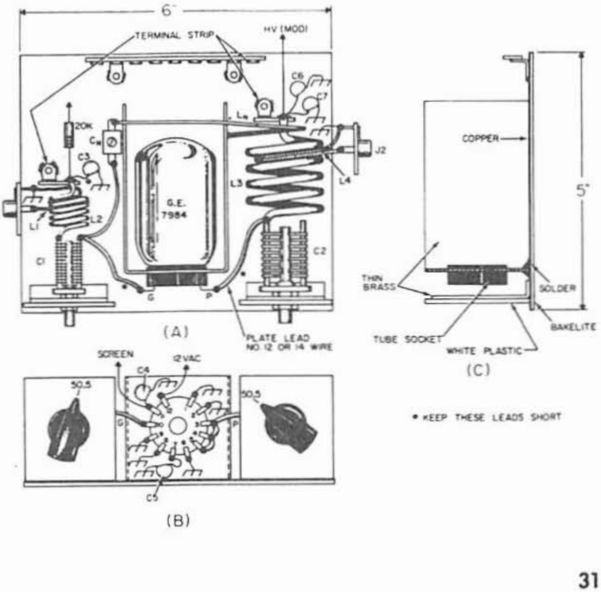


Fig. 3. Recommended layout for the 7984 final amplifier.

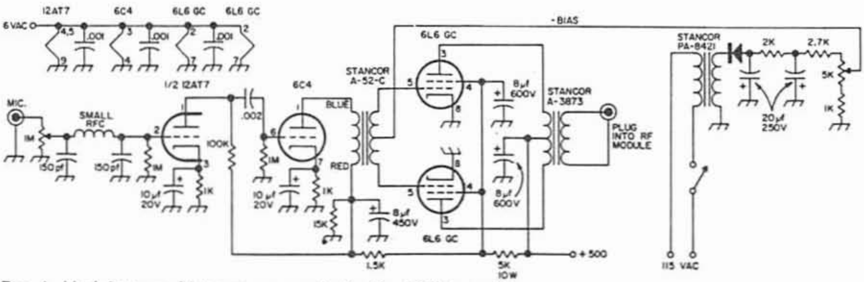


Fig. 4. Modulator and bias power supply for the 7984 amplifier.

Station assembly

This is an important part of the station, and can really run up the cost if you're not careful. For transmit-receive switching, I use a two position, four pole ceramic switch fastened flat against a copper-clad bakelite panel with three coaxial cable braids soldered to it up real close to the switch contacts. Be sure to use a ceramic switch.

The other three poles open or close the receiver voice coil and switch the 275 and 500 volt power supplies. This is done on the AC side of the rectifiers. There is a slight drift on the crystal VFO as the filter capacitors charge up, but it always settles down immediately to the same spot.

I find it best to use one small power supply for the exciter and a larger 500 volt supply for the modulator and final. Actually, it would be better to use three supplies, with separate ones for the rf final and modulator. You can use any supply you have around from, say, 300 to 500 volts. Over 500 you're on your own.

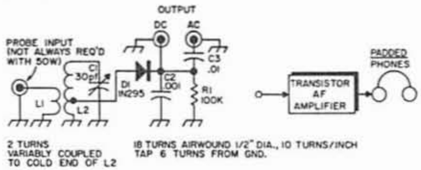


Fig. 5. RF detector for checking the six meter transmitter.

For carrying the station around, I use a set of wood shelves with the exciter and rf at the top shelf, the modulator next, and the power

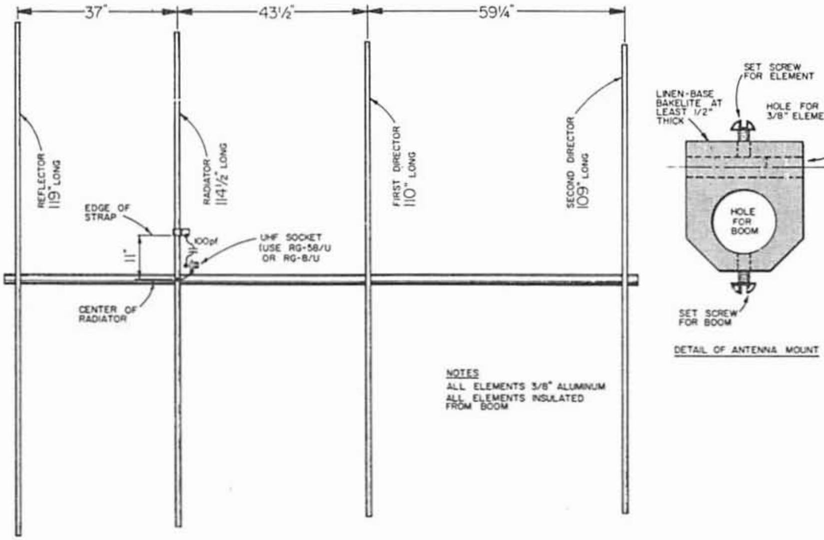


Fig. 6. Four element six meter beam. Good for about 10 db gain.

supply on the bottom, with a piece of dowel on the top for a handle.

RF detector

As a final check I find it indispensible to listen to my own modulation. Also for hum or distortion on the carrier. This is by no means easy to do properly. The usual receiver does not do a good job at all. What *does* do a good job is a handy-dandy assembly as shown in **Fig. 5.** This set-up with a long pointer knob for good resolution between 46 mc and 50 mc makes a very useful piece of test equipment. Do not use a regular tube type of amplifier. The padded earphones are also a must. It's very simple. With your ears shielded from your own voice as far as sound goes, a good bit of audio gain, you can hear exactly what you sound like, right in your own shack, using a dummy load if you wish. Note that you are listening to yourself on a receiver and you can hear any hum, distortion, feedback, etc., can be heard instantly. You cannot pick up frequency drift or FM on such a receiver, but you can check those on a regular communications receiver.

Four element beam

This rig has been used so far with the four element beam shown in **Fig. 6.** This is a little firecracker and really pushes the signal up about ten times in power (10 db) in one direction while taking it away from another one, of course. If you make it exactly as shown, it will have the same power gain. It's shown as a rigid array, but you can adapt it to portable use with folding joints without too much trouble.

. . . K1CLL

Exciter Coils

L1. 7 turns airwound, 16 turns per inch ⅝ in. diameter. B & W 3003, Air Dux 416T.
L2. 6 turns of plastic covered No. 22, ¼ in. O.D., ⅜ in. long. Inside L1.
L3. 2 in. of ½ in. dia. 32 turns per in. B & W 3004, Air Dux 432T.
L4. 15 turns of No. 28 dcc wound on cold end of L5.
L5. 13 turns airwound 8 tpi.
L6. 2 turn adjustable link over cold end of L5.

Using Low-Cost FETs on Six

Field effect transistors (FET) seem to be the answer to converter design for the 50 MHz amateur band. The cross-modulation problems common with ordinary transistors and even with tubes are no longer a real headache when using these new transistors. Ordinary transistors are subject to overload and cross-modulation with more than about 20 millivolts input which means that local stations can ride in on weaker signals anywhere in the amateur band. An rf stage ahead of the mixer even with tubes (less overload characteristics) will usually amplify a local station 100 KHz or so away from the desired signal enough to cross-modulate it in the mixer stage. FET types of transistors as mixers have extremely good characteristics for reducing cross-modulation and will even permit the use of an rf amplifier in most locations. Ordinary transistors and even some tube mixer types will often overload enough with an rf stage circuit to make them useless in some locations.

The FET units have been expensive for use in the vhf region and often have exhibited poor noise figure values. The writer recently obtained some new FET plastic-cased transistors for approximately one dollar apiece from a Texas Instrument distributor. These were TIM12 units which have very low NF and good gain values at 50 MHz. A circuit of a good 50-MHz converter is shown in Fig. 1 and illustrated in the photographs. The converter was built on a scrap piece of copper-plated board 1½ x 6 inches for mounting into a 6 inch wide aluminum chassis. The noise figure measurement between 50 and 52 MHz was from 1.5 to 2.5 dB. This is very low and means that in nearly all locations, antenna noise pick-up will completely override the receiver noise.

The cross-modulation capability was checked by connecting two signal generators to the input jack. One signal generator was connected to the converter input thru a 10 dB pad and, with no modulation, was set to give an S5 or S6 signal reading in the *if* receiver when the whole system was tuned to this signal frequency. Then another tone modulated signal gen-

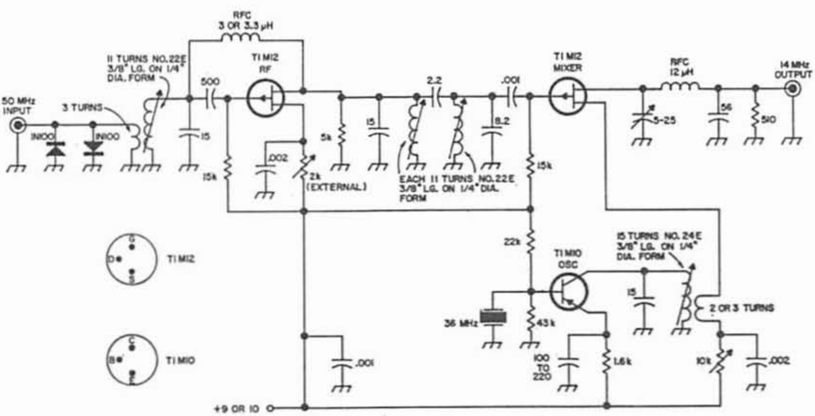
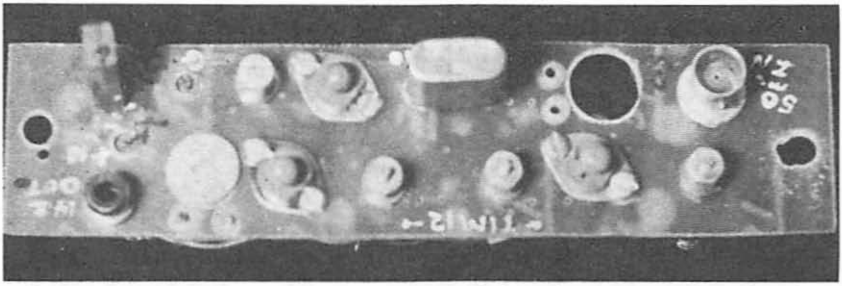


Fig. 1. 50 MHz converter using field effect transistor rf amplifier and mixer. The FET's cost about $1 each. This converter has a noise figure of around 2 dB and great resistance to cross-modulation.

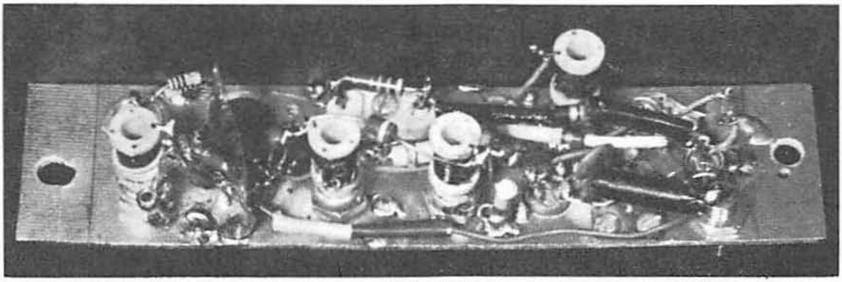


Top view of W6AJF's six meter FET converter. The extra hole by the BNC input jack was used for neutralizing trimmer that proved unnecessary.

erator was turned on at about 1 MHz off frequency (connected directly to the converter) and its output attenuator adjusted until some over-riding tone modulation was heard on the cw signal generator. It took more tone signal than could be obtained thru the attenuator which was supposed to have 100,000 microvolts maximum output. The "one volt" output jack produced appreciable cross modulation. It was estimated that it took about ¼ volt to produce objectionable cross-modulation. It was necessary to have a large resistor pad between the converter and the *if* receiver, and to have the two test signals separated far enough apart so the cross modulation problems in the *if* receiver were negligible. It is surprising how poor some homemade and some commercial radio receivers are for cross modulation in the 14 MHz region. It would seem that FET transistors should be used in all 14 to 18 MHz and 5 or 2 MHz if and mixer stages right up to the main sharp mechanical or crystal filter in the *if* section. A 20 dB pad on the *if* receiver input helped to reduce these effects while trying to check the converter only. The added pad or attenuator was only a stopgap cure since the real cure is to use a better designed *if* receiver.

Surprisingly, the IN100 back-to-back diodes in the receiver input were not troublesome in these cross-modulation tests. These diodes are standard on all my converter inputs in order to provide some transistor protection from moderately high powered transmitters at this station. The 1N100 diodes have a low capacitance, reasonably high back resistance and quite low forward resistance and are low cost types. Connected across the coax input jack, the diode loss is very low and it does provide some added protection against destructive surge voltages from the antenna system or switching relay.

The converter rf stage required some neutralization by means of a 3 or 3.3 microhenry rf choke connected between the input and output tuned circuits. This resonates roughly at 50 MHz with the gate to drain capacitance of a TIM12 which is typically about 3 pF. Even with this amount of inductive neutralization it was necessary to load the tuned input circuit down to quite



Bottom view of the low noise, low cross-modulation FET converter. The copper shield is across the rf amplifier socket. The solenoid rf choke at the other end is part of the pi network output circuit.

a bit less than 1000 ohms by means of the antenna link of three turns. The FET has high input and output impedance and a 5000 ohm resistor across the output tuned circuit was also needed. A variable source resistor of 2000 ohms was mounted external to the converter to permit easy rf gain adjustment.

The FET mixer stage in this unit has gate signal input and source oscillator injection. A small Trimpot, 0 to 10,000 ohms, provides bias for the mixer stage. This pot and the oscillator pick-up link of 2 to 3 turns were adjusted to provide minimum cross-modulation effects. Actually a 2-kΩ or 3-kΩ fixed resistor would be quite satisfactory for this type of transistor and oscillator injection voltage. The latter is greater than with ordinary transistor mixers, but should be a little less than that which gives maximum mixer gain. At the maximum gain value, the cross-modulation effects are worse. The mixer output circuit is a pi coupling network tuned to about 15 MHz. The dc path resistor across the output jack can be made much lower in value if a wider *if* frequency response is needed. The value will be somewhere between 50 and 500 ohms for most *if* receivers. If the latter actually looks like 50 to 70 ohms, the dc shunt resistor can be of a higher value.

The 36 MHz crystal oscillator uses a TIM10 or any other VHF transistor which will produce strong 36 MHz output with one or two milliamperes of collector current. The emitter bypass capacitor produces regeneration and its value will usually range between 100 pF and 220 or even more for most types of PNP transistors. The FET TIM12 units are P-channel which is similar to PNP transistors for battery supply polarity. Some FET units are N-channel which require the same supply voltage polarity as NPN transistors. The TIM12 has an odd base arrangement of leads (see Fig.1) as compared to ordinary transistors. This can cause some confusion in wiring up the transistor sockets and requires a little care in checking over the circuit wiring before fixing up the converter.

As a final comment, this converter showed a 25 to 30 dB improvement in cross-modulation as compared to several other 50 MHz converters using ordinary vhf transistors of several types. It also had a better NF than the other converters. The spurious signal responses were less due to the FET mixer.

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Slippery Six

The heterodyne vfo can be particularly important to an amateur, because you can move around the band, spot in on local operating portable sets. This of course is caused mainly by the variation in the dielectric of capacitors, and can be avoided by the use of air dielectric. It is also divided by twelve in this rig, and by 18 on two meters. So if you have only air types you will be better off. This rig does have a mica compression trimmer in it but so far that has not bothered at all. Again, it just doesn't really seem fair to make comparisons between this vfo and others. Heating of oscillator components caused by other tubes in the rig. There are only three of these other tubes, including the modulator tubes. Mixer, final, and modulator. And they are also quick heating filament types. Same 5618 of course, with not much heat in them. If you push the final to its full 7½ watts dc input you will get a little more, but not much. If you use the flat "open" type of construction these last tubes will be a little distance away from the oscillator. That is good for other reasons too. Like rf feedback. "Leaving the oscillator running." Along with all the other evils found in the "usual" vfo, this is a rather nasty one and has led people to heterodyne mixing of oscillators at low frequencies simply to get the transmitter off your own frequency where you rag chews when mountain-topping or mobile, without the usual work involved in setting up a "stable vfo".

One half of a 3A5, 55c double triode is used as the high frequency crystal oscillator, the other half as the low frequency variable oscillator. The crystal oscillator 46 megacycle output is fed into the control grid of the 5618 quick heating pentode mixer, and the low frequency variable oscillator, 4 to 5 megacycles, is fed into the screen grid of the same tube.

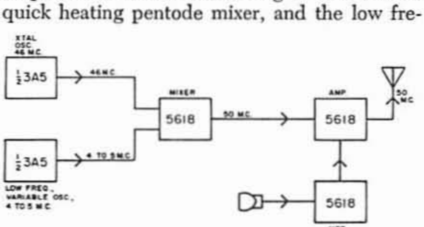


Fig. 1. Block diagrams of heterodyne rig.

On the plate of such a mixer can almost always be found *four* frequencies. The fundamentals, 4 and 6 megacycles, and the sum and difference of those two. We will use the sum in this rig.

The reason, for these last two frequencies, is a fascinating subject. Several eminent scientists have written large, good, and costly books about just that one subject. A good number of special tubes have been created just for this service. They are also known as converters in receivers, and as modulators in transmitters. However, we are not going into the theory of mixing here, intriguing though it is. We will have enough to do to make up a good practical rig for battery-portable use, with the main emphasis on why such a design can be made very stable "without hardly trying at all".

The Principle

The principle involved is very simple. Instead of a vfo on low frequency which has to be *multiplied up*, a vfo on low frequency is *added* on. That's all there is to it. A drift, or shift, in the low frequency is *not* multiplied. Example: With an 8 megacycle vfo to take the place of an 8 mc crystal, the 8 mc must be multiplied by 18 to reach 144 mc. Any drift, shift, hum, or what-have-you is also multiplied 18 times. With the heterodyne vfo, no multiplication!

The Circuit

The 3A5 triode, each section, does not have much gain so regeneration is used in the crystal feedback circuit. It is not too critical, when used as shown. It just helps to start an otherwise sluggish crystal, keep it going, and provide more output with less critical tuning. Enough reasons?

The low frequency oscillator is also very simple in design. The only thing borrowed from the "conventional" vfo is the use of a fairly high C. A lot of other things often found in vfo's can be thrown away. But, don't forget, there are basic reasons why you can do this here, and *not* do it in the usual vfo. Most of these reasons go back to the main principle

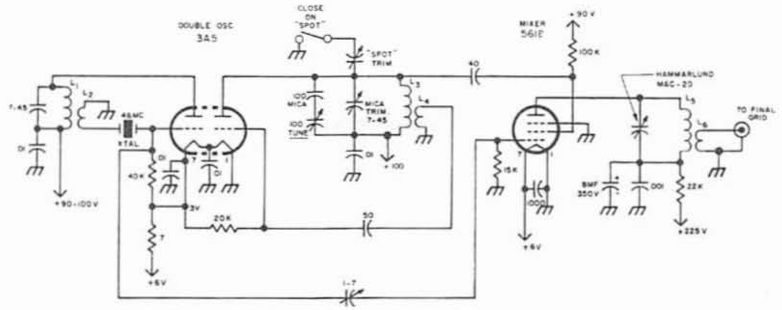


Fig. 2A. Double oscillators and heterodyne mixer.

of *adding* instead of *multiplying*. 1. Mechanical stability. Not requiring high Q, as the oscillator is a "regulator" type, with plenty of feedback, the inductance L1 can be small and light and does not vibrate mechanically, even when you're walking around with it. 2. Heat. The 3A5 is a quick heating filament type tube that does not heat up enough to cause any noticeable drifting, or heat up any of the other components either. In fact, it is turned on and off every time you transmit and receive, as are all the others. 3. Absence of temperature sensitive capacitors. When you use a lot of capacitors across an oscillator coil you often find yourself with frequency drift, especially when getting in and out of cars and may be listening. And generally are today. The quick heating tubes obviate that one.

So, seems like enough reasons to me. Granted that the remedies for all of these troubles are made easier by the non-multiplication of the variable oscillator frequency. But that's just the point of this entire rig!

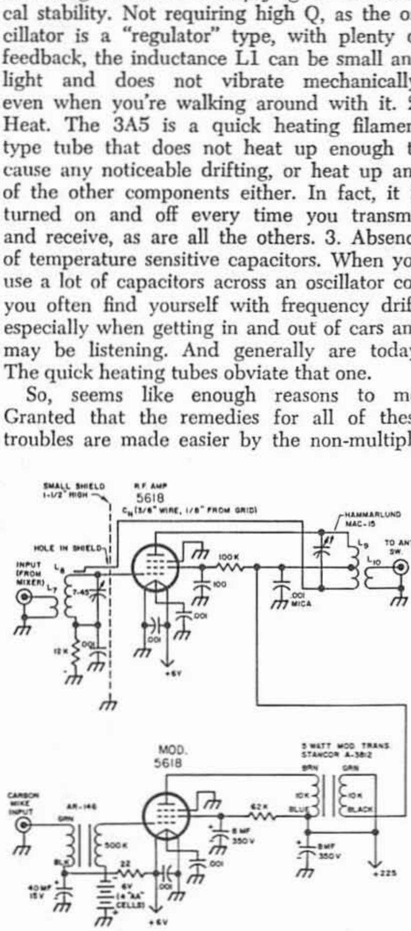


Fig. 2B. RF final and modulator.

The Transmitting Mixer

Now that we have two stable frequencies, one fixed and the other variable, what do we do with them? The crystal oscillator 46 megacycle output goes to the 5618 pentode mixer grid because, being in the VHF region, it does not have much output, for a transmitter, and needs the grid-plate conversion transconductance of the pentode mixer.

The low frequency variable oscillator can have more power (but don't exaggerate on this idea!) and be used to modulate the screen grid. Be sure and keep in mind the meanings of the words mixer, converter, and modulator. The principle and processes are the same but the useage can be different. Note that with the rise of SSB to favor in many quarters we now have people on the air every day talking about converters. They don't mean receiver converters either, they're talking about transmitter converters.

Note the high value of the screen resistor in the mixer, and the dropping resistor in the plate supply. Mixers are particularly fussy about these values, and the bias on the grid or grids. This does *not* mean that they are critical.

Control grid bias and screen grid voltage, should be varied under operating conditions for optimum desired results. In this rig it has already been done. The desired results were the maximum output at 50 megacycles from the 5618 mixer with given inputs from the 3A5 and the *least* possible output at 46 megacycles. Also the least at 42 mc, although this latter is no great problem, since it is 8 megacycles away from 50 mc.

Just a word here about the choice of frequencies for the double oscillator. It is obvious that one should not go too near 50 mc,

because it would be too difficult to filter out the fundamental crystal frequency (46 mc). Also, the lower you go with the crystal, the higher you must go with the variable low frequency oscillator. It then becomes more and more fussy.

Tuning the plate circuit of the mixer, which of course should be of the highest possible Q (use airwound coils), you will find both the crystal fundamental at 46 mc and the sum frequency at 50 mc. Be very sure about which is which! I used both a tuned power detector and absorption frequency meters on this job. A grid-dipper in the diode mode is also OK. Use a number of checks on this point! Do not use your high gain sensitive receiver! It helps to have some kind of a marker or small dial on the mixer plate tuning capacitor. Once you get the mixer and the two rf final tuning capcitors on 50 mc you will have no trouble at all from then on.

The RF Final

This operates quite conventionally with the 5618 neutralized. We used a piece of heavy wire, with good flexible tubing over it through the shield wall, brought over near the grid. See Fig. 2b. Works fine. A bakelite screwdriver bending the wire nearer or further away from the grid without rf excitation (watch those plate mils!) shows oscillation or neutralization immediately. Remember, the .24 mmf Cgp isn't much of a capacity but it is enough to make a high-gain unloaded pontode oscillate. You can do an even more precise job using a power diode detector on the rf final output with excitation but no plate or screen voltage. We neutralized this particular rig about a year ago and it has not budged since.

Again, air-wound coils are used in grid and plate circuits with coax link coupling. Be very sure you are on 50 mc! The rest is straight-forward rf circuitry and works OK. Once all three major tuning capacitors are on 50 mc you will have no trouble.

The Modulator

It uses high level modulation and is quite uncritical. Be sure to use fixed bias on the grid return and just remember that the 5618 likes class A audio. There is not much current upswing when talking. At the 5 watt level this class A type is still very good. You could make up a class B stage, but why? The storage battery driving the 225 volt hv transistor power supply might hold its charge a few minutes longer, so what? And you would have more and different tubes to buy and use.

Again, for the microphone, don't use anything but a Western Electric F1 button.

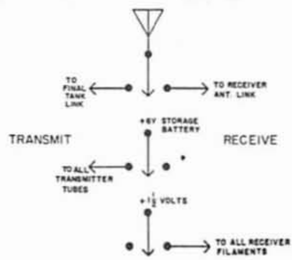


Fig. 3. Switching connections.

The Spotting Circuit

Let's face it, the 6 meter band today, especially evenings and weekends resembles the ten meter band in those vintage sunspot years, '39, '48, and so on. This situation settles the rock-bound versus moveable question. That is the main reason for this article. On top of that, the rig is fine in the car, real quick like, with a rain-gutter antenna, UHF connector, cable through the little vent window, and possibly a jumper over to the car battery to keep the portable one charged ready for hiking up on top of the hill away from other mobileers! I have found that the whip up from the rain-gutter at some 45 degrees is very good. Kind of takes care of both beams and other whips. Incidentally, a whip has a stiff gooseneck at the bottom which is very handy for fixing in position and still allow for those low-hanging branches you will find on those high country roads.

When you arrive at that hill-top and get on the air, you will hear all kinds of local (5, 10, to 15 miles) rag chews going on. If you are rock-bound you might as well have stayed in bed. With the circuit shown you flip the spot switch, zero beat, and you are ready to cut in at the proper moment.

There is a little deal on the power used for spotting. As shown, the 3A5 alone gives just about the right amount of power for the job. The 3A5 filament should be connected to the spotting switch for this business. I have not shown a complete organization of the switch, because many different possibilities are feasible. We actually use a 45 volt B battery for the receiver section, and add another making 90 volts for the 3A5 supply. You might want to drop down from the hv supply for this. Watch out for modulation on the supply though, if you do.

Notice the "spotting trimmer". This turned out to be quite important and a great help.

It is needed to avoid the following trouble. If you want to be able to hear the station that you are zeroing in on, you cannot turn on the full rig. If you do not turn on the full rig you will not be on frequency. So the little trimmer takes care of that real neat like. To adjust it, tune in the transmitter full power on another receiver, shut off the transmitter and turn on the spotter, without touching the receiver. Adjust the trimmer till the spotting frequency is the same as the transmitter. That's all. Just do it once and forget about it.

Send Receive Switch

This also comes out of the Storage Battery Portable rig. Simple deal, using short connections on the transmitter, receiver, and antenna cables. For cables I have used both RG-58/U and the small ⅛ inch miniature 50 ohm cable. Both are ok. See Fig. 3.

For Antennas. Don't forget the gooseneck whip, the telescoping folding dipole, and the 4 element beam that folds up into a golfbag.

. . . K1CLL

Solid-State Slippery Six

A really low cost practical heterodyne VFO rig for six meters is described. The Sprague 2N1726 transistors used are listed amateur net, quantities 1 to 99, for only $1.15. And as you will see they are actually easier to handle and tune up than tubes, once you get used to them. No line cord, no transformer power supply, just a small 9 or 12 volt battery and away you go, shack, car, or on foot.

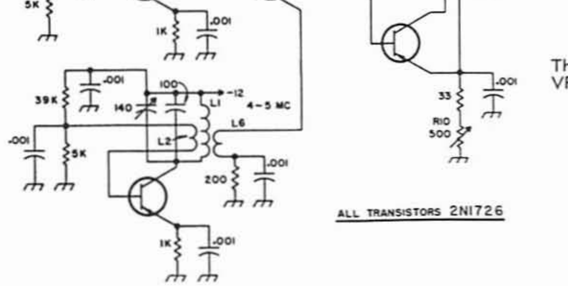
Fig. 1 is the schematic. Both oscillators are strong oscillators having been maximized for gain and efficiency and will work at very low voltages which is always a good test for oscillators. The 4 to 5 mc one uses a collector winding L1 made of No. 26 DSC, two pi, each 25 turns, for a total of ⅜ inch. L2 is wound between and over the two sections. The coil form is impregnated paper with internal thread and a 6/32 threaded core for adjustment. You can use another form if it tunes 4 to 5 megacycles with a total capacitance close to that shown in **Fig. 1**.

L2 is 6 turns No. 30 DCC and is wound in the same direction as L1 and the base then goes to the opposite end from the collector. For the fixed capacitor across L1 use a dipped silver mica. The crystal oscillator is just as straightforward and neat. L3 is 9 turns of ⅜ diameter air wound, 8 turns per inch, and is tuned to 46 megacycles. L4 is two turns small plastic covered wire wound on top of L3 near the middle. If L4 is wound in the same direction as L3 connect the base to the opposite end from the collector, and you can't miss.

In both these oscillators the 1K resistor in the emitter will protect the transistors whether they are oscillating or not. A milliammeter in the mixer collector return lead to the minus 12v during tune-up will serve as an RF indicator for the oscillators if you don't have a handy-dandy RF detector.

The mixer does not need external DC bias as it is driven by the RF from the oscillators which develops the correct amount of bias on the 200 ohm emitter resistor. Transistors are natural born mixers. This one gave out with lots of 50 mc immediately on being fired up.

L7 tunes 50 to 51 megacycles and is 10 turns of ⅜ diameter air wound, 8 turns per inch. L8 is semi-adjustable. We used about 1½



The six meter solid state heterodyne VFO exciter.

turns on the cold end of L7. Not critical, but it pays to trim up for power and tune-up for frequency.

The RF amplifier does not use any external DC bias either as it develops what it needs in the emitter resistor due to the rectifier action in the base-emitter diode circuit.

The variable 500 ohm resistor can be replaced by a fixed one but there is a consideration here. The 2N1726's are low cost low power units and when you light a No. 48 or 49 bulb bright you are pushing them. So the 500 ohm variable is known as a "drive control" and works quite well at it. I would suggest somewhere around 10 or 12 mils collector current for the two RF finals in parallel.

L9 is 10 turns airwound, 8/per inch, not critical. A No. 48 bulb across 2 or 3 turns from the cold end of L9 will light up dull red with R10 set at 100 ohms and over, and fairly bright with R10 at zero ohms. Once again, watch those collector mils!

If you want to push things even a little more you can add two 1.5 volt cells to the minus 12 volts, 15 volts total, and get out like mad. You should have some spare 2N1726's on hand though!

. . . K1CLL

Six-Meter Jewel

Since many hams do not have rack mounted equipment, the resulting conglomeration of cables and chassis is usually not scenic. The average ham, by nature a procrastinator, never quite gets around to removing the haywire appearance which is normally generated in his anxiety to get the new rig on the air.

If signal reports are satisfactory, appearance be darned! The rig works swell (the ultimate goal) so why worry. If anything goes wrong with the rig, we'll take care of it then.

Pictured here is a 6 meter gem designed and constructed by W3CMA and K3PXT. Two identical units have been constructed, the only variation between the two is a result of parts available.

The cost of this unit is negligible since most of the parts have been salvaged from discarded idiot boxes. Parts not available from passe boob tubes were purchased surplus.

Most important is the feeling of pride with the statement, "Well the rig here is homebrew," while surveying the neat compact rig that you have built and are operating.

Circuit description

The power supply uses a single transformer for both low and high voltage. The low voltage section uses two 6AX4's in a full wave rectifier circuit. Capacitor input insures minimum hum in the audio circuits. The high voltage circuit consists of a 5U4, combined with the rectifying elements of the 6AX4's as a bridge circuit. Choke input provides good regulation for the 6146. A dpst switch removes the dc voltages from the plates of all tubes for standby operation, while simultaneously deenergizing the Dow Key ant relay.

The rf section uses a 5763 as an electron coupled Hartley oscillator which tunes from 8.3 to 9 mc. The tuned circuit of the oscillator is loaded with a high C to L ratio for good stability. A voltage regulator supplies the screen grid (oscillator plate) which is electron coupled to the plate circuit. This electron coupling isolates the oscillator from the following stages. The combined high C to L ratio, voltage regulation and electron coupling results in a very stable vfo with effectively negligible frequency shift.

The plate circuit of this stage is a frequency tripler, capacitance coupled to the following doubler stage. The doubler is in turn capacitance coupled to the input of the final at the operating frequency, with a very healthy 4 to 5 ma of grid drive throughout the entire 6 meter band. The output of the final utilizes

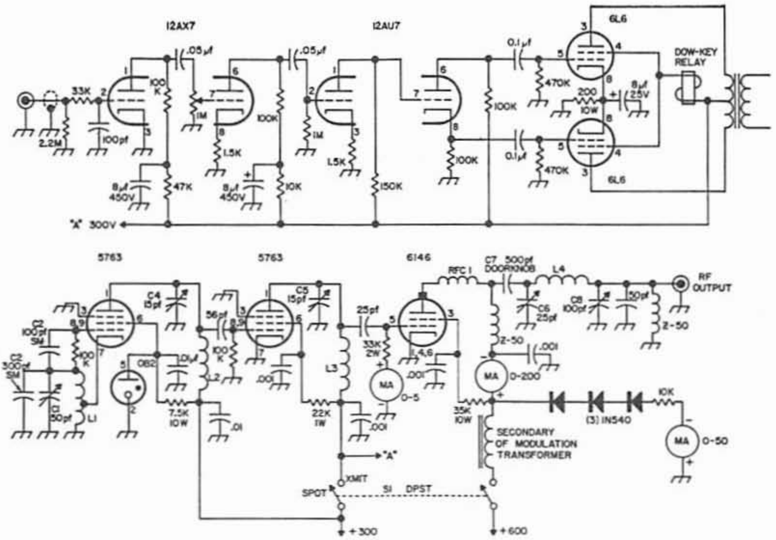


Fig. 1. The Six Meter Jewel rf section and modulator.

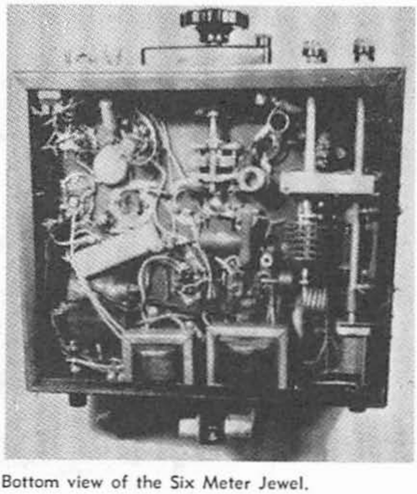
the very flexible pi-coupled network for greater harmonic attenuation, and relatively constant impedance throughout the entire band. An additional advantage to this method of coupling is that it may be used at some future date as the input to an amplifier for additional power, when deemed necessary.

The modulator section is straight forward, using three stages of RC amplification before a direct coupled hot cathode paraphase amplifier, which feeds a pair of old reliable 6L6's, operating class AB1, for plate modulation. The unbypassed cathodes of the amplifier combined with the direct coupled paraphase amplifier, results in excellent frequency response. Most important, however, is the elimination of an interstage transformer's space and cost.

Construction

The complete transmitter is constructed on a 12 x 10 x 3" chassis. The front panel is 12 x 8". Its sole purpose is to mount the meters. The meter at the left is the modulation indicator which at the time the pictures were taken was not wired in because of the author's inability to scrounge the necessary diodes at the time. This meter is used to ascertain that modulation does not exceed 100%, thus avoiding splatter and distortion. The center meter is the final amplifier plate current and the meter to the right is the final grid. Using the proper shunts, multipliers, and switch, one meter can be used to monitor these circuits. The individual meters provide simultaneous monitoring of the important circuits and an instant indication of any difficulties that may arise during transmissions.

The oscillator dial (lower center) is a National Velvet Vernier drive. This unit requires no mechanical change and is mounted directly to a Hammerlund MC 50S variable capacitor. The dial is marked 0 to 100. A calibration chart may be used for frequency identification,



Bottom view of the Six Meter Jewel.

or the spot switch technique of zero beating the receiver can be used to determine frequency within the calibration accuracy of the receiver. The latter method, of course, is the most practical.

The 6146 final is mounted in a horizontal position beneath the chassis. Small holes spaced ½ inch apart on the top and side of chassis provide sufficient ventilation for cooling. This method of mounting the final makes efficient use of space that would normally be wasted.

In general, the layout is simple. There is no crowding of component parts, ample room for wiring and soldering, nor is the rig constructed elevator fashion (level on level) as can be seen from the photos; practically all component parts are easily accessible for trouble shooting when required.

Calibration and adjustment

The rf section is adjusted for proper frequency stage by stage with the aid of a grid dip meter. The over modulation indication meter is adjusted as follows: speaking normally into the microphone adjust the modulation control until the needle deflects sharply upwards at speech peaks. The upward swing of the meter now indicates that modulation is in excess of 100%. Now slowly turn back the modulation control to the point where meter movement no longer occurs at peaks.

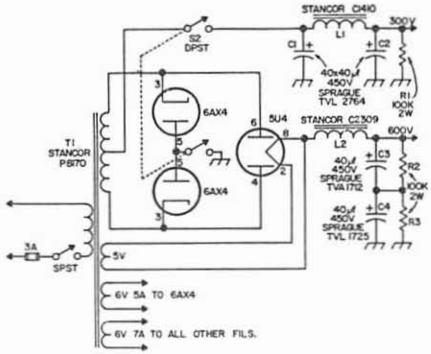
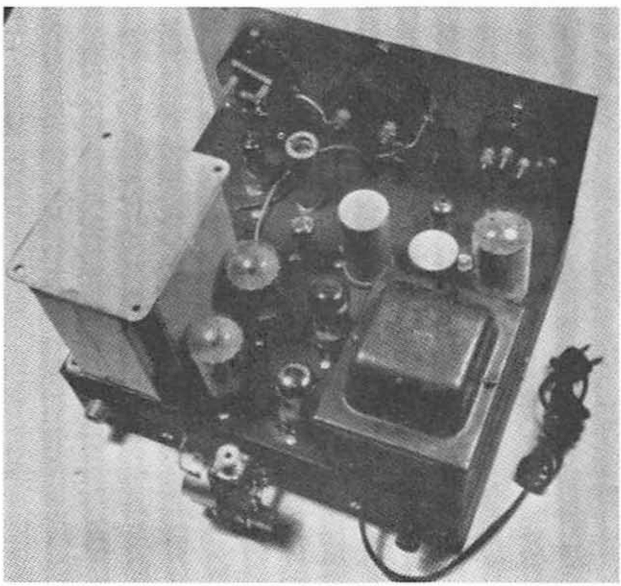


Fig. 2. Power section of the Six Meter Jewel.

The meter effectively eliminates the need for a scope for modulation adjustment and permits easy adjustment for obtaining 100% modulation with no fuss.

The filaments should be set to on, at least a half hour before operation to ascertain minimum drift of the oscillator, however, the longer the filaments are on the more stable the oscillator. Set the Trans. Rec. switch to Trans. and adjust the tripler tuning and doubler tuning for maximum grid drive. Adjust the plate tuning for minimum plate current and the plate loading for maximum indication. Alternate between the two until a plate current of 120 ma is obtained.



Top view of the Six Meter Jewel.

When changing frequency, it is not necessary to retune the transmitter unless the grid current drops below 3 ma; it is only essential to redip the plate tuning and adjust the plate loading.

This rig as constructed is ideally suited for the ham who has a limited operating space, its size is such that it is easily transported from Qth to Qth during periods of mobility (vacations, etc.). . . . K3PXT

Coil Table

L1. Oscillator, 9 turns number 20 on ¾" ceramic form. Tapped third turn from cold end.
L2. Tripler, Like L1, but no tap.
L3. Doubler, 5 turns #18, ½" diameter, ⅝" long.
L4. Plate, 5 turns #14, ¾" diameter, ⅝" long.
RFC1. 6 turns #22, ¼" diameter, spaced wire diameter.
RFC2, 3. Ohmite Z50.

Six-Meter Heterodyne VFO Transmitter

Compactron tubes have many advantages for ham use. They were developed for commercial applications where their main advantage is economy: They are squat tubes with 12 pins, set in an all-glass envelope. Because of the large number of pins, most Compactrons contain more than one unit. For instance, the 6J11 has two completely separate and shielded high gain if pentodes, each with a Gm of 14,000. That is high. Compare it with 4300 for the 6BA6! The 6D10 has 1½ 12AT7's in it. That's three good triodes of 2½ watts dissipation each. The 6M11 has two of these (12AT7) triodes and a 14k Gm type 6EW6 as well. In addition, the Compactrons have a large pin circle diameter for more insulation and higher plate voltage. Tube leads are also short and direct for good high frequency performance. You can see the many possibilities for amateur use.

We built a two tube VFO heterodyne transmitter using one Compactron. The final tube is an old 815, but could easily be one of the Compactron power tubes. The most interesting part of the circuit is the heterodyne, or conversion, VFO, where a stable 3 to 4 Mc variable oscillator is added to a 47 Mc crystal oscillator in a mixer. This avoids multiplying the VFO output, so the mixer output on 50 Mc will be very stable as the crystal oscillator can easily be made drift-free.

We started the transmitter with a 6AF11, which has a triode and a 6CX8 in it. This tube is very useful for the heterodyne circuit. As soon as I put the 12 pin socket in *one* hole, wired up *one* filament lead and soldered three cathode tabs to the tube ring, we began to appreciate the economy of labor involved with Compactrons. We checked the various sections of the 6AF11, which has two good triodes and a super-dooper video type pentode with five watt dissipation (almost a 5763). These tube people may be nervous about transistors, but they're not surrendering peacefully. Those triodes are good! The 47 Mc crystal oscillator starts off with only 8 volts plate voltage. And the pentode section puts out one watt of stable six meter energy even though it is acting as a mixer. All this is one small bottle for $2.

Now to the details. I used the highest gain triode for the 47 Mc oscillator, since it needs the gain. Fig. 1 shows the circuit. L2 is inserted in L1. The coupling may be varied for tests but it is not critical. It is important to keep the plate voltage below 100 volts. You can use a voltage regulator if you like, but we didn't find one necessary.

The Variable Oscillator

Here again, a good plate circuit is set up. After all, it's the plate that generates the power. An airwound coil is used, tuned to 3 to 4 megacycles. There are some who maintain that the plate should be grounded to avoid "heat expansion trouble." They perhaps forget to mention that the plate-grid capacity is still present and would cause frequency shift if the plate did expand with heat. This one is stable, as is.

An air capacitor is used as a parallel pad to set the frequency on the dial. Here also you are interested in a certain amount of power. Don't forget, this is a transmitting circuit. C4 is a Hammarlund MAPC-100 with a screwdriver shaft. C3 is a Hammarlund MAPC-100B with ¼ inch shaft. They are air capacitors so they will not vary with temperature. C5 spreads the frequency out on the dial. The variable frequency control portion may be made a lot more fancy if you like, with slow-motion dial, switching for every half megacycle, etc. We just brought the shaft out with an insulating extender and put a long pointer knob on it.

The crystal oscillator is fed into the grid of the pentode mixer through C2, a 1 to 5 pf mica compression capacitor. For adjustment of C2 first open it up and get the crystal oscillator running properly, with a gradual increase in grid current (open the ground end of the grid resistor and put in a milliammeter) on one side of resonance, and an abrupt drop on the other. The presence of the regenerative coil (L2) makes the operation much less critical, as you can check. As you increase the feedback of L2 you will see a greater region of power out and less abrupt drop. C1 should tune to resonance near the middle of its range. With the oscillator running proper-

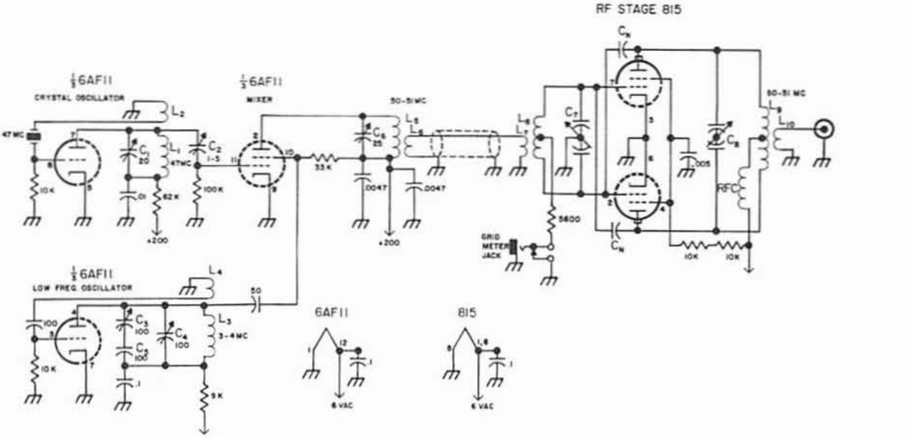


Fig. 1. 6 Meter Heterodyne Transmitter.

L1. 7 turns airwound, 16 turns per inch ⅝ in. diameter. B & W 3003, Air Dux 416T.
L2. 6 turns of plastic covered No. 22, ¼ in. O.D., ⅜ in. long. Inside L1.
L3. 2 in. of ½ in. dia. 32 turns per in. B & W 3004, Air Dux 432T.
L4. 15 turns of No. 28 dcc wound on cold end of L5.
L5. 13 turns airwound 8 tpi.
L6. 2 turn adjustable link over cold end of L5.
L7. One turn link near center of L2.
L8. 4 turns No. 14 enamel, 1¼ in. O.D. 1 in. long.
L9. 6 turns No. 14, ¾ in. O.D., 1½ in. long.
L10. 2 turns near center of L3.
C1. Hammarlund MAC-20.
C2. 1-5 pf mica trimmer.
C3. Hammarlund MAPC-100B. "Tune."
C4. Hammarlund MAPC-100. "Set."
C5. 100 pf silver mica.
C6. Hammarlund MAPC-25B.
C7. Hammarlund BFC-12.
C8. Hammarlund BFC-12.

ly, increase C2, putting more power into the mixer grid. Too much C2 will knock out the crystal oscillator and cause self-oscillation of the pentode. It is very stable over the useful range though.

The variable oscillator is coupled into the mixer screen with a 50 pf capacitor. This section worked perfectly right away and has not drifted since. It is very uncritical and very stable.

The mixer plate is simply another good 50 Mc coil, tuned with a Hammarlund MAPC-25B air capacitor. With both oscillators running, 47 Mc and 3 Mc, peaks of energy will be found at 44, 47, and 50 megacycles, the sum and the difference of the two oscillators, and their fundamentals. The 3 Mc fundamental naturally does not show up in a 50 Mc plate circuit. We obtained about one watt out of the plate on 50 Mc. Do *not* ever use this on

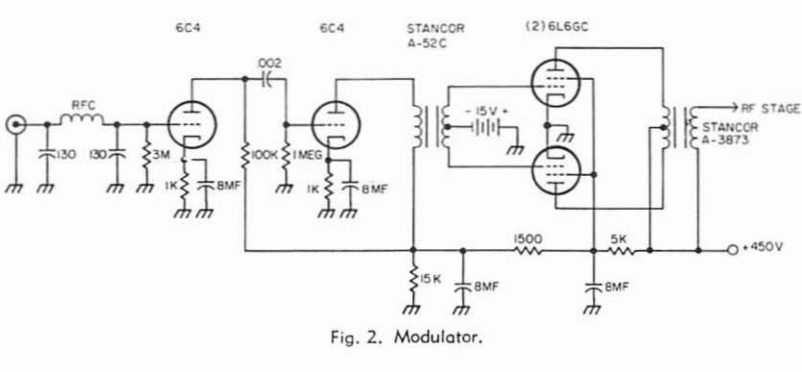


Fig. 2. Modulator.

the air without at least two more tuned circuits, as the 47 Mc energy is only some 10 db down. Link coupling over to the final grid circuit of an rf amplifier, such as an 815, plus a good plate circuit on the 815, will result in the 47 and 44 Mc energy being way way down.

The RF Stage

Almost any good tube that will put out 25 watts or more and operate on 1 watt input on 50 Mc will do. I used my old favorite, the 815. It neutralizes easily and can be bought for as low as $1.75 surplus. Fig. 1 shows the circuit. It is quite standard; tunes up easily; and the neutralizing holds once and for all.

The Modulator

Fig. 2 shows the modulator circuit. It works, and works good enough so that the modulation reports were "better than average," "clear as a bell," and "no trash or hash of any kind."

After getting the 6C4 driver stage running, We put another 6C4 in front and plugged in my low-cost Astatic mike. Immediately, rf feedback. This time I was able to cure it with an rf choke and two 130 pf capacitors between the mike jack and the grid. No feedback at any time since. The two 6C4's just about do the job, but only just. I'm going to put in a 6AT6, which has a much greater amplification factor.

VHF crystals will *not* stand over 100 volts on the plate of the triode. Increasing the dropping resistor and lowering the volts on the plate to 100 you can take out any drift that you may have.

For frequency spotting, the 6AF11 power supply is switched on without the final. It puts a large signal into the receiver, but with a beam antenna on the receiver you can hear the desired carrier through it. . . K1CLL

Two-Watt 6-Meter Transmitter Using the Heterodyne VFO

This section describes the breadboard design, tuneup, and results of an rf power stage on 6 meters using the $2.95 Motorola 3-watt HEP-75 transistor (similar to the famous 2N3866). This rf stage is designed to work from an input power of 120 mW such as furnished by the 6 meter crystal-heterodyne-vfo circuit described previously.

Circuit and Design Theory

Figure 1 shows the schematic, using the input matching network. The design of a VHF input circuit can take various forms, depending on whom you read, what you read, and the proposed use of the rig. In this case, we want sure-fire operation, an easy-to-build circuit, freedom from self-oscillation, smooth tuning, 12V operation, and "carrying" type portability for hill-topping emergency use, and mobile work, as well for use at home.

The circuit in Fig. 2 uses a capacitor from J1 to the base. It works, and should be sufficient in the case of an excess of input power (not too likely), and where you don't mind adjusting cable length. However, if you're building up from only

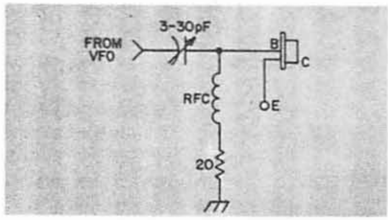


Fig. 2. Simplified input circuit, 2 watt, 6 meters. (Temporary)

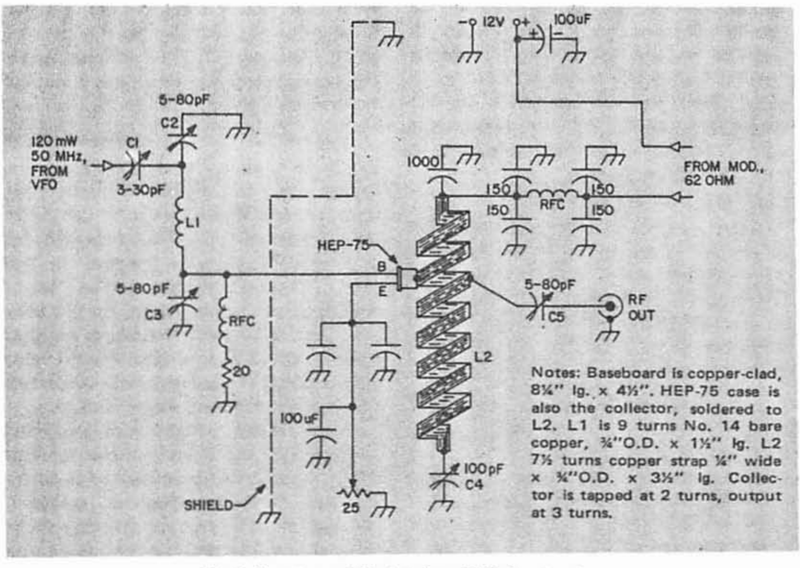


Fig. 1. 2 watt, crystal-heterodyne-VFO 6 meter rig.

120 mW of vfo output, you may want maximum power transfer along with the ability to match various cable lengths, and direct inputs (as in the case of packaging the entire rig in a box).

The circuit of Fig. 2 is reliable and good for a "quickie" any time. But it does not always furnish maximum drive or best input match unless the cable length and output tap on the vfo output inductor are adjusted. These latter are of course indications of mismatch, but for short lengths of cable there is little loss, so you can operate that way if needed.

DC Base Lockup

This nasty little trouble has not been mentioned in the rather large amount of literature persued here through recent years. I can just hear some know-it-all lads saying, "Ho, Ho, he's just discovered the Poniatowsky effect." Well, maybe so, but whatever its name is, it arrived here and I don't like it! Here's what happens: With an rf choke from the base to ground and *no* resistor, and an rf input driving the collector to about 200 mA, cutting off the rf excitation does not cut off the collector current. There is no rf involved and it seems to be a dc type of hangup. Just for fun I'll wait until someone tells me its name. In the meantime, back on the breadboard, the cure was easy. Just include a little resistance in the base circuit. That's why the 20Ω job is there.

Input Matching and Base Circuit

After trying out various combinations of circuits as shown by RCA, Motorola, Fairchild, and others, the circuit of Fig. 1 was judged best. Inductor L1 can also be an air-wound coil 5/8 of an inch O.D., 8 turns per inch, with 5½ turns (not too critical).

Just a word of caution here about overloading receiver inputs while testing transmitters. While checking with the lab receiver, with its antenna only 10 in. away from the 1W rf output of the amplifier, the receiver was completely blocked out and detuned by the rf. The addition of only 1 in. of wire as a test antenna brought things back to normal. A very peculiar effect; expect almost anything when you start to run power. In solid-state VHF, "power" refers to anything over 1W.

Emitter Circuit

No trouble here. Two capacitors were used for bypassing, which are not really 100% in parallel. That is, with the ground leads of the capacitors going to slightly different ground points and the two leads cutting down the lead inductance by a large factor, the emitter is pretty well tied down to the ground plane rf-wise. A 25Ω pot controls power output from about 0.25 to 1.0W with 120 mW of rf input power and 2W of dc power.

Due to the base resistor requirements, no limiting resistor was needed in series with the 25Ω emitter pot which operates nicely as an rf power control (although 2W dc input does not particularly strain the HEP-75). A 100 μF capacitor was later shunted from the emitter to ground for better modulation properties.

Collector Circuit

Several requirements must be met here, some of them not usually compatible, but things worked out quite well as you will see in the results section. A good high-Q inductor is desirable for maximum selectivity when loaded by the antenna, and at the same time good heatsinking is needed. Fortunately, there is a design that will accomplish both of these requirements at the same time. The secret; Plenty of copper. Thus the edgewise-wound copper-strap inductor shown in Fig. 1. The collector is internally connected to the case, and to keep the inductance low and the heat conductance high, the case can be soldered directly to the copper strap. Do not use a large iron, and be sure to tin both the strap and the transistor case first. Use the minimum amount of time and heat to do this, consistent with a good solder joint.

Note that the collector is tapped pretty far down on the inductor (near the cold end); this is done for impedance matching purposes. With direct currents of nearly 200 mA at 12V, you can see that the rf impedance will be low. This gets to be a big problem when you get up into the hundreds of watts, but at 2W matching can be done by tapping the collector on the second turn of a 7½-turn coil as shown.

The copper strap also takes care of the heatsink problem by conducting the heat away from the collector in both directions along the strap. With more powerful tran-

sistors, use is made of a beryllium oxide or aluminum oxide insulating stud, which conducts heat quite well but *not* electricity. So far they cost a lot more, but we can always hope they will come down in price.

Collector Dip Notes

With the HEP-75 collector circuit detuned, the current is near 200 mA; with it tuned and unloaded, the current drops to about 50 mA just like in the good old days with tubes. Believe it or not, a spark can be seen when applying the pencil test to the high rf end in the unloaded condition. I generally load the circuit with the antenna so that a slight dip of, say, 10% is obtained. With an rf power indicator in the antenna line a precise adjustment can be made.

The RF Output Match

While not critical, the output connection does require care and testing to obtain a good match and maximum power output at 50 MHz.

Tapped onto L2 and 2½ turns (Fig. 3) is a 5–80 pF Arco compression trimmer (Model 462), which does a good job of matching a 0.9 or 3W bulb to the collector. With the input circuit of L1 tuned correctly and 180 mA showing in the collector circuit while detuned, and rocking C4 slowly through the dip at resonance, the proper adjustment of output coupling capacitor C5 can be obtained.

The adjustment for a pilot light match is not necessarily the same as for a 50Ω cable. Leading to coax requires readjustment of output capacitor C5 and possibly the tap on L2.

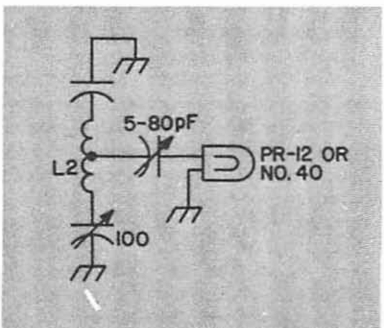


Fig. 3. Output test circuit.

I found 160 mA to be about the maximum output. If you load L2 down to where there is less dip, your power and selectivity against harmonics will suffer. It is best to use a shade less coupling, sacrifice a small percentage of your power, and obtain good discrimination against harmonics. (Don't forget that second harmonic of 50 MHz right in the middle of the FM band!)

Homebrew Wattmeter

There are rf wattmeters on the market but they start at $49.50 for 2–30 MHz and go up in price along with the frequency. With all the material that the young builder has to purchase, perhaps on an "allowance" budget, he just has to pass up such luxuries.

Most catalogs list many different lights with a wide variety of wattage. You can push these along at a lively dc clip to perhaps twice the rated voltage. After all most of them sell for only 15¢ to 90¢. The only thing is that after you get up to a watt and over it begins to be a little tough on the eyes! So use a higher rated lamp than actual rf power.

A lot depends on what you can find in your local hardware store if you're in a hurry right now to know how many watts output you have. There comes to mind the question of whether or not the pilot lamps light to the same brilliancy on rf wattage as they do on dc. All I can say is that when a lamp is lit by rf to the same brilliance there must be *at least* that much wattage. If the final is tuning nicely at the proper loading point, as mentioned above for maximum power out, it is reasonable to suppose that most of that rf is going into the filament of that pilot lamp, and will show up as heat.

To make a real handy wattmeter for pennies, set up a little panel or minibox with lamp, battery, pot, and dial knob calibrated in watts. To calibrate, simply read the amps times volts for different positions, using the method of successive approximations to get round numbers for easy reading on the dial.

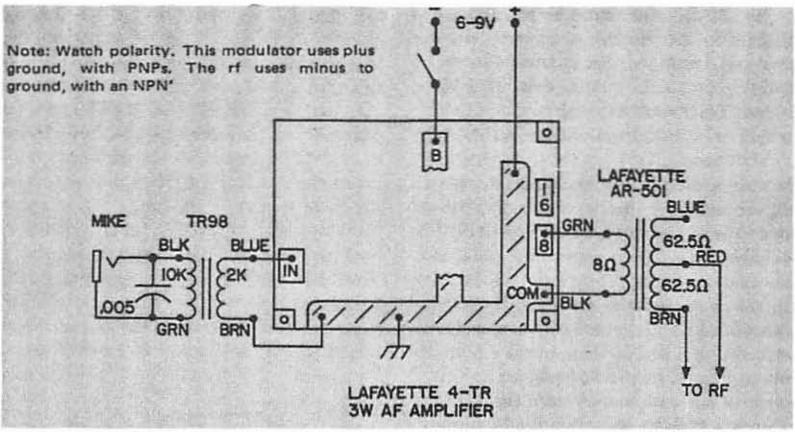


Fig. 4. Modulator circuit, 2 watt, 6 meter rig.

To solder a connection onto the aluminum base of a bulb, use a good clean tinned iron, scrape the aluminum clear of any oxide, and use a rubbing motion of the iron to tin the aluminum for about 3 or 4 seconds. Friction, plus heat and solder flux, helps solder to adhere adequately to aluminum.

For use with the transmitter, just position the wattmeter bulb alongside the one lit by the rf and adjust for the same brilliance. The human eye is supposed to be quite good at this type of comparison. It works.

The Modulator

There is a ready-made unit for the modulator, which only costs $7.95 and has 3W of audio output. This is the Lafayette "4-TR," 99E91432. It is a chunky little package, uses an RC-coupled input stage, a transformer coupled driver, and two power transistors in push-pull, with an output transformer having 8 and 16Ω outputs.

The unit fully modulates the 2W rig. It may well be that certain systems need transformers, and others,

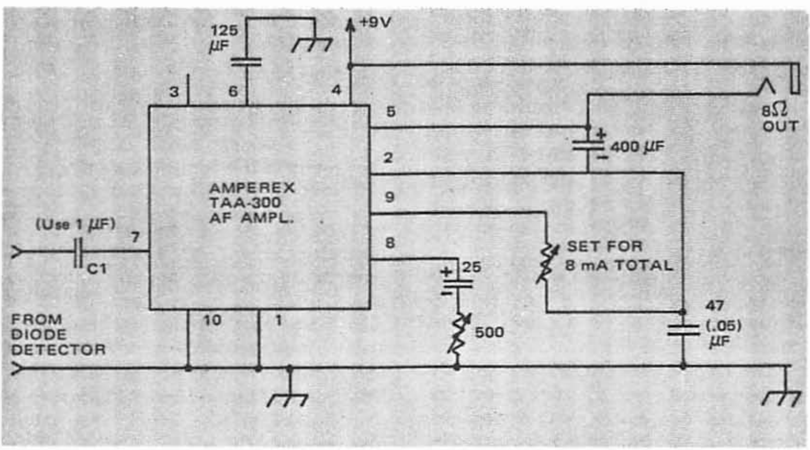


Fig. 5. Modulation monitor, 2 watt, 6 meter transmitter.

such as hi-fi sets, are better without them. As some engineers have pointed out (mainly those engineers from telephone companies!), the best of FM broadcasts reach you through a minimum of ten or a dozen transformers, so why worry about one more?

So, for a modulation transformer, not having found the ideal as yet, we use another, back to back with the 4-TR winding of 8Ω, The nearest to 75Ω I could find was the Lafayette AR-501, which has an 8Ω winding on one side and a 125Ω winding on the other (centertapped). It worked out fine on the air, in the circuit shown in Fig. 4. As the power goes up on this type of rig, with one or more HEP-75s, possibly to 10W or so, the modulation impedance will drop below the 48Ω region. In this area there is the 10W "universal" transformer with taps at 4, 8, and 16 on one side and 8, 12, 16, 24, and 48 on the other side, at only $3.95. A major benefit of low-impedance solid-state devices now becomes evident, as you don't have to pay for much copper.

A good idea for checking your own modulation on a dummy load before you put it on the air is to use an Amperex TAA-300 integrated circuit, as shown in Fig. 5. This little gem is actually a miniature hi-fi set all by itself, and it really tells you what your own rig – with *your own voice* modulating it – sounds like to others on the band. To do this you need also a set of earphones, with good padding to keep your voice from reaching your ears through the air. The Lafayette Model 8X stereo headphones ($7.95) are excellent for this, with 8Ω impedance per phone. Just connect the two phones in parallel in a three-circuit jack.

Connect a tuned diode receiver in front of the TAA-300 to pick up the rf from the transmitter, and use the Amperex external circuit as shown in Fig. 5.

The TAA-300 is an excellent example of a modern audio-type IC using eleven tran-

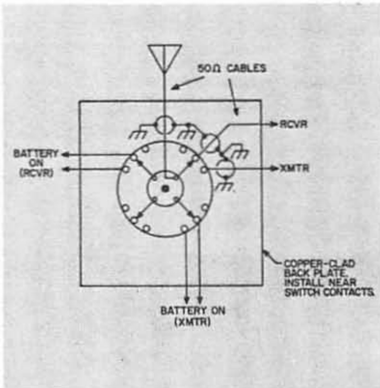


Fig. 6. Send-receive switch, 6 meter, 2 watt transmitter.

sistors and five diodes, with a frequency response of 20 Hz to 25 kHz. Naturally, you don't need all that range for voice communications work so the following modifications were used to cut down the highs and reduce the lows. Replace C1, 0.6 μF, with a 0.01, and install a 0.005 across the input jack. Regular treble and bass tone controls can be made up but they should be put in a minibox to minimize hum because there is a lot of gain at 60 Hz in the little tin can. We also put a pot in place of the 48Ω feedback shunt resistor, because making the negative feedback control variable has very interesting possibilities, as you will see when you operate it. The TAA-300 also makes an ideal amplifier for any amateur receiver using transistors.

On The Air

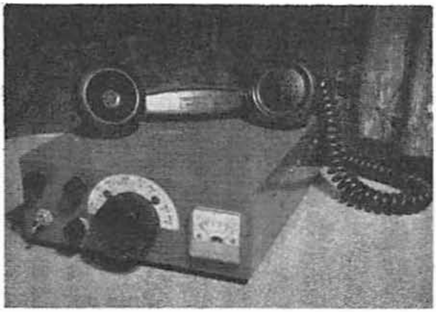
Not waiting to hook up an rf power monitor, I connected the 50Ω cable from my 4-element beam through a ceramic rotary switch for use as in Fig. 6, to change over the antenna and turn the receiver and transmitter on and off, and tuned for the same dip in the collector current that had shown maximum power into a PR-12 3W pilot lamp. This did the job... K1CLL ■

A Portable 6-Meter Station

The set consists of a crystal-controlled converter, a tunable *if* receiver covering 7 to 11 mc/s which is also handy for listening to CHU, a crystal-controlled transmitter taking 25 mc crystals, and a class-A modulator with clipping. There are 17 to 20 transistors, depending on whether you incorporate the optional final, BFO and squelch. The drain on receive is under 20 ma at 12 volts, and on transmit about 250 ma. With eight MN1500 penlite cells ($2.64 worth) you are set for a long day of hamming, or about 30 hours' net operation with a loudspeaker. Two F4BP lantern batteries ($1.58 total) will go about three times as long. The ten-cent penlight cells will poo out after a half dozen transmissions, so don't bother with them.

The receiver, so far as we can tell, is good enough. There is some cross-modulation from strong local stations, but many "tube" receiving setups are as bad. The sensitivity is good, about 5 db noise figure including the losses in the protective circuit. The selectivity of the prototype was at one time adjusted to be 3 kc wide at 6 db down and 20 kc at 60 db, about the same as the early HRO's, but the coupling was later modified to make the receiver a little wider for net operation, by increasing the coupling capacitor between the pair of *if* coils to the value shown. It's still more selective than the older Gonsets.

Receiver drift is small, and what there is, is not caused by the transistors. Regulated voltage is used on the tunable (second) oscillator and its associated mixer to get away from battery voltage shift as the cells recover from a transmission. Transmitter drift is much less than found in tube transmitters using the same crystals, although the circuit was set up for maximum output.



The antenna tends to be heavier than the transceiver. Hi-Par makes a portable beam (we don't have one) which should be fine. For walk-around use, like at hamfests, a center-loaded piano wire whip does the job. In any case, there is a problem setting up the transmitter, and you should have a sensitive tuned field strength meter with some provision for monitoring with headphones. Currents don't change much with tuning, but modulation quality is critically dependent on the tuning of the final. There is sidetone provided to the earpiece of the WE handset, but it only tells you that the modulator is working. Rf power transistors for use at 50 MHz are a bit of a problem. Since both the driver and final have modulation applied, the required breakdown voltage is a little less than four times the battery voltage for each stage—say 48 volts for BV_{CER}. If BV_{CBO} is what the manufacturer specifies, it should be over 60, in our experience, i.e., type 2N1506 performed ok but 2N1505 and 2N2297 appeared to break down on modulation peaks, causing flat-topping. (A Tektronix 545A with suitable plug-in will allow you to view the rf envelope across a 50-ohm load, if you feed the audio in as an external trigger.) The high-frequency performance of types used for 27-MHz CB rigs is seldom good enough, but it might be worth while to try a few dozen to find a good one. In general the ratings on rf transistors don't include AM, but a type rated at 1 watt out at 28 volts at 70MHz should be good for a quarter watt AM carrier output at 14 volts at 50 mc if you have enough drive (typically at least 110 mw.). When better transistors are made, you can expect that we'll try to use them at even higher frequencies (where as usual they won't work very well!)

The reason both final and penultimate stage are modulated is that with low gains and what is roughly class-B operation, modulating one stage doesn't seem to work. Also, neither

the final nor the driver should be loaded for carrier conditions, but (like a Gonset linear) they should be tuned and loaded for best "upward" modulation. Since the transistor gain is much higher at, say, ten mc than at 50, there is a good chance of having parasitics at several mcs, though not much likelihood of trouble above the output frequency. A trick peculiar to transistors comes when the collector (in these NPN's) swings in a negative direction as the base goes positive to the point that current flows from base to collector, and for an instant in the rf cycle the output and input are connected. In one instance, this was found to react back to cause the oscillator stage to stop, giving an extremely overmodulated-looking output (the modulation envelope pinched off completely) and an extraordinary amount of buckshot. FM comes much easier.

The transmitter schematic is shown in Fig. 1. Useful carrier power output is about 1.5 watt,* with fairly good audio quality. To transmit, plus 12.6 is applied to the complete transmitter by the send-receive switch or relay. A type 2N706 or similar is used in the 25-mc oscillator. The circuit tunes like a triode tube oscillator, that is, the tank should be a little bit on the high side of crystal frequency. With a few exceptions, CB oscillators will work fine in this position, but not all makes of 2N706 work well. Fairchild and PSI seem to be better for rf work than others.

The second stage doubles from 25 to 50 mc. The oscillator tuning may be checked by observing rectified base current across the 820 ohm resistor. A relatively high-c collector tank is used at 50 mc. Note that some transistors of a type may have higher than rated breakdown voltage, but don't bet on which ones.

The driver is pretty ordinary. Neutralization is not used; large-signal amplifiers cannot be neutralized exactly, because the base-to-collector capacitance is a function of the voltage between the two elements, i.e., it's a varactor. The modulation can be applied in either the positive or negative lead, since there is no heater or filament insulation problem, and we chose to put it in the negative lead in order to make it possible to use a center tapped choke in conjunction with a pnp power transistor. The rf chokes and ferrite beads specified are what we used; a small solenoid wound on a 47-ohm resistor would probably do as well as the beads, if the latter are not obtainable.

The modulator is designed for a carbon mike. To use a crystal mike (ceramic, if you will be in the hot sun) would take two more transistors. The first stage is NPN, since we are using negative ground, and its collector current flowing through a silicon diode provides bias for the other transistors. Two silicon diodes across a miniature choke (a transistor radio output transformer) clip the speech waveforms at about 1.3v peak-to-peak. An emitter follower using just about any PNP alloy transistor drives a power transistor operating class-A. If you cut the carrier when you have nothing to say, a class-A modulator amplifies square waves as efficiently as class-B. Any auto radio output transistor will work, although the 2N1172 (TO-37 style) miniature unit would be much smaller and about the

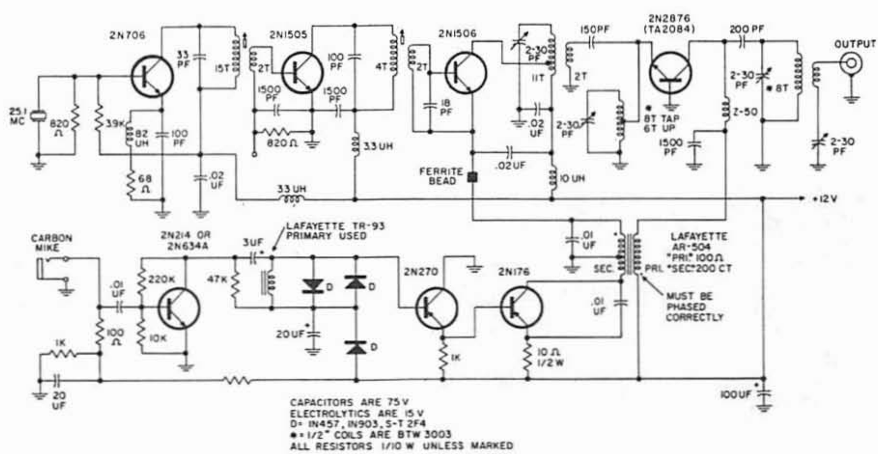


FIG. 1

same price. The unbypassed emitter resistor in that stage is adjusted to such a value that the current through the two halves of the choke is about the same. The center-tapped choke will be about half the size of the choke that would be needed for Heising modulation.

Construction—General

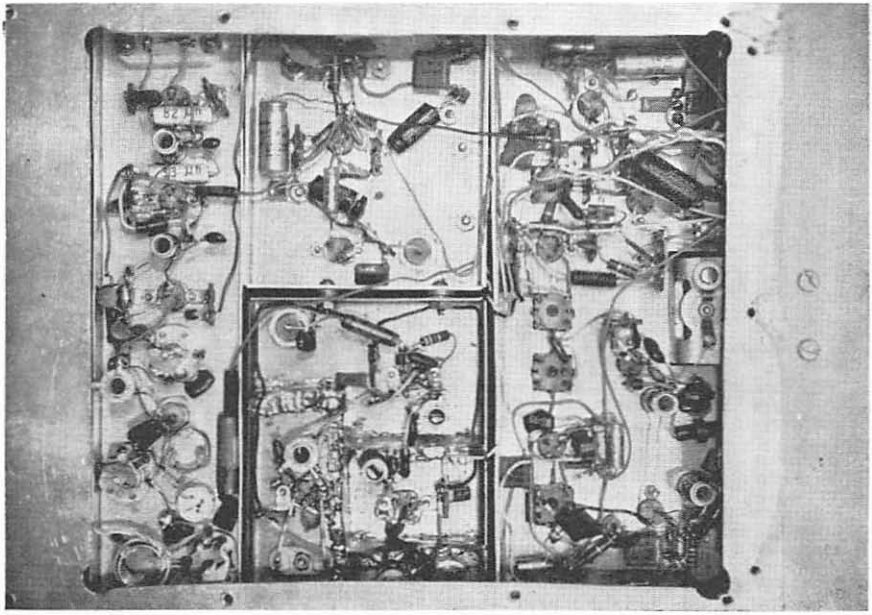
This transceiver was built in a commercial 8 × 12 × 3 aluminum chassis. The smallest face becomes the front panel. Four chassis were built up to fit the available space, with the receiver full width next the panel, then two half width units for the modulator and the converter, and finally the rf section in a chassis about an inch and a half by eight. Batteries went in the rear, but the photos show the fourth stage on the transmitter, with external batteries being used.

As the photos show, the open side of the chassis was fitted with a cover plate, while the other face was mostly hacked away to allow access to the other side of the subassemblies without removing them.

The main mechanical problem is to get adequate tuning precision and mechanical stability in the receiver; it should be fitted so as to make sure the dial and tuning capacitor line up right, which is best done by first mounting the dial, then connecting the T C, and then spotting where the tuning capacitor mounts on the chassis. Send-receive switching is done with a wafer switch. Only two poles are really needed, as the audio amplifiers are separate.

Heat and heat-sinks. The silicon transistors in the rf section will work satisfactorily without any heat radiator, although they get hot. Thermalloy #2211 heat sinks (in Lafayette's catalog) help quite a bit, and it wouldn't hurt to put the same type on the audio output transistors, if TO-5 size are used. The modulator power transistor is mounted on the aluminum chassis with the mica insulator supplied (at least it is with Delco types) for electrical insulation. Check for and remove all burrs in the area covered by the mica. Run your tongue over it to check for smoothness.

Components. The individual units were made up on .040 aluminum chassis to simplify grounding and shielding problems, except the converter, which was made of 0.031 brass, so that shields could be soldered in place. Sockets were used for the transistors, a great convenience when there is a desire to try vari-



Transmitter Modulator Converter Receiver

ous types. We used saddle mount sockets (Elco 05-3301) with four pins which would accept TO-5 transistors directly, as well as TO-40, 2N43, 2N78, 2N270 and TO-11. Other types such as TO-7, which has a shield lead, TO-44 which has leads close together, TO-1, TO-18 and such can be plugged in by arranging the leads properly. The sockets were mounted with 2-56 brass hardware. Solder lugs for no. 2 were made by using the small end from standard size solder lugs. Model railroad hobby shops have the small bolts and nuts.

Resistors. We used several styles. Our advice is to use ohmite (Allen-Bradley) QUARTER watt types. The half watt use too much space, the tenth watt type are impossible to wire without tweezers and a jeweller's loupe —and the color code is hard to see—but the quarter watt size is just fine. Lafayette had some Japanese desposited-carbon resistors which were very fragile, and the small Globar resistors came apart when the soldering iron got them too hot. An Ungar pencil iron on a Variac worked well, but the smallest GE iron with a resistor in series (cut out by a foot switch) was even more convenient.

Capacitors. The electrolytics were C-D type NLW (easy on the leads, some broke off first bend) or assorted Japanese. The coupling and AGC electrolytics might be Mallory TAM or

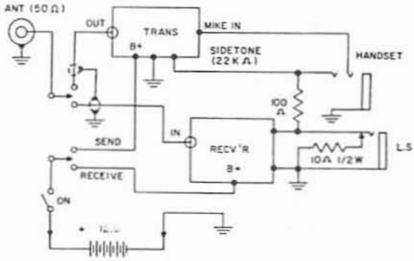


FIG. 3

similar, though the aluminum type is satisfactory. The rf and *if* bypasses were mostly 75-working-volt ceramic types from Lafayette, with some 10-w.v. ceramics used as base-return-to-emitter bypasses where there normally is no more than two volts. You've never heard a noisy component until you put 12 volts on a 10-volt ceramic capacitor. Like frying bacon.

Battery mounting. If internal penlite-sized batteries are to be used, they may be mounted in commercially available clips which hold a group of two to four cells, bolted to a wall of the case. We have had trouble with these after rough handling (the transceiver is just the right size to drop!) from the batteries getting askew and not making good contact. It is suggested that the batteries should be accessible for voltage check under load or physical inspection *without a screwdriver.* A piece of insulating material held in place over the clips would also prevent cells coming loose. With the F4BP lantern batteries there should be no problem, since it is easy to keep the binding posts tight. Certain types of closed-circuit type plugs or the equivalent could be used to hook into an external power source. The MN1500s appear to take several partial "recharges," so maybe it would help to plug into the car battery with the internal cells still connected: a blocking diode (1N91) is suggested to avoid trouble from reversed polarities or low external voltage.

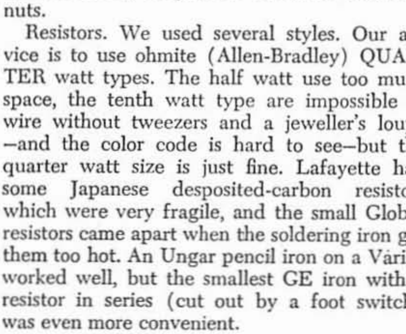


FIG. 2

To tune up a transistor interstage with a grid dipper, you apply collector voltage to the previous stage, make sure the base return (coil or whatever) is in place, and disconnect the emitter lead. The driven stage should have collector voltage disconnected. Now you have 12 volts or so between collector and base of the previous stage, so the C-B capacitance is approximately what it will be when things are going, and the next stage has zero bias. Couple loosely to get a sharp dip; if the GDO signal is more than a few hundredths of a volt current will be drawn and the capacitance will be changed. A transmitter interstage set up to dip is shown here.

There is no substitute for a good transistor in the first stage. The rf amplifier used is grounded-base. A silicon computer diode (not just any type, check the numbers) is used as a limiter at the input in hopes that strong 50-mc signals will not immediately melt the first transistor. Transmitter leakage is not bad, but what if the transceiver with whip attached is carried by a mobile just when he goes on transmit? A good check on the diode is that it should make no difference on weak sigs, on or off.

The double-tuned coupling helps keep Radio Moscow off six meters, but if some oscillator juice should get back to the rf input, there is still a chance of interference. We used 0.010 copper (sheet? foil?) for shields.

The circuit shown in the transmitter, adapted for PNP, should work as well. The main thing is that the oscillator should start reliably and not move around with voltage changes. Required drive to the mixer is a couple of milliwatts. Mixer injection is somewhat fussy. Because of the fancy bias network, mixer current will only change a few per cent with the proper amount of injection. If in doubt, use less, so as to reduce the birdies and the spurious responses.

Roughly speaking, the 50-mc input impedance is the same grounded-emitter or grounded-base, about 30 ohms at the usual currents. The rf stage might as well be a premium type (still under three dollars) and the rest can be any type recommended for TV or FM use. See the section on the transmitter for tips on grid-dipping. The mixer plate lead feeds a pi-section low pass filter which is intended to reduce the quantity of 43 mc signal delivered to the 7-11 receiver. If this is very strong, it will combine with harmonics of the second oscillator in the second mixer to give birdies (in pairs) each time the 2LO harmonic gets 455 kc away from the 1LO frequency. The pi-section interstages are also intended to reduce the transmission of 43 mc. Tapped-coil coupling, used in the prototype, was quite bad in this respect, as the taps seemed to resonate in the 40-50 mc region.

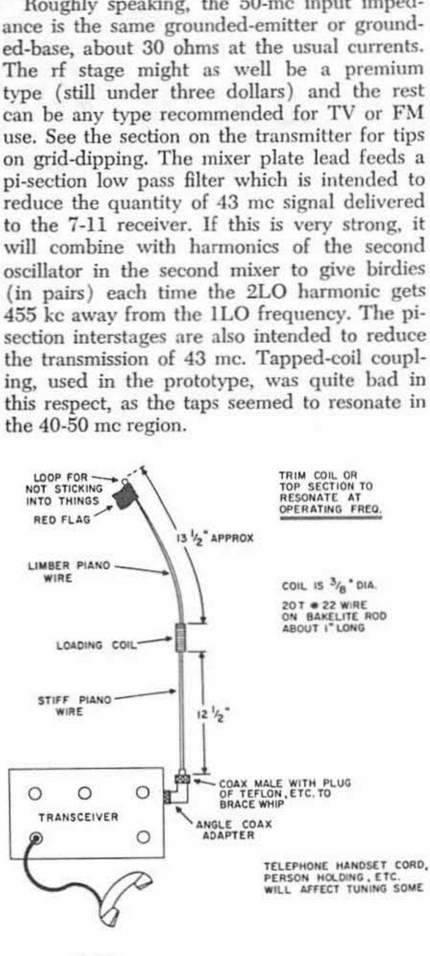


FIG. 4

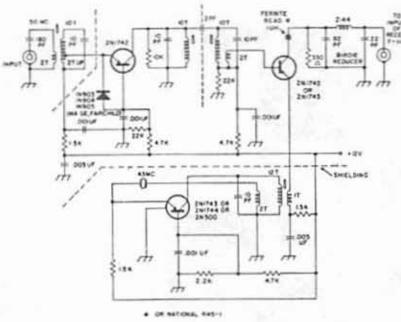


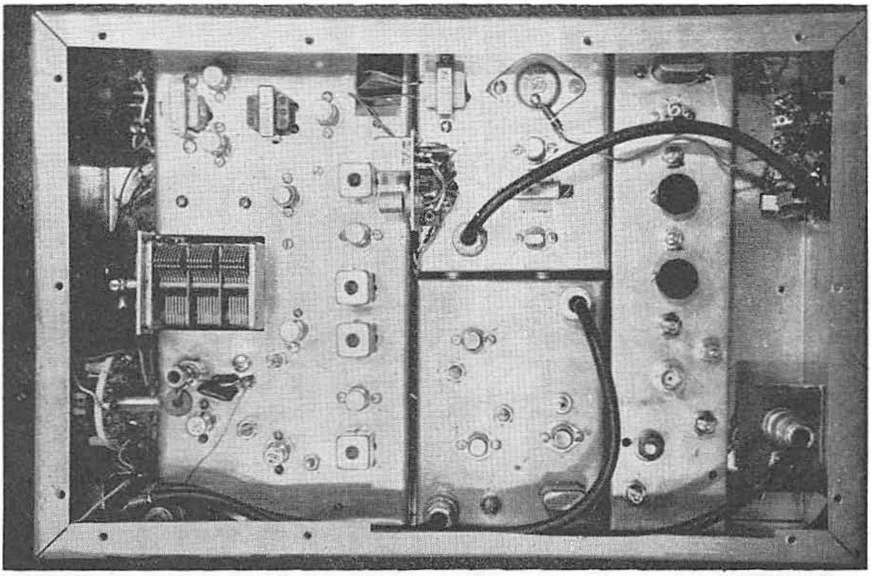
FIG. 5

All resistors ¼ watt, all capacitors mmfd, all coils on ¼" ceramic tuned forms.

The converter and receiver amplifier stages are unneutralized. Per-stage gains are fairly low by design, and the MADT, PADT and "drift" transistors used have very low collector-to-base capacitance. They are cheap enough that there's no point in substituting.

The 7-11 mc "tunable *if*" is a complete receiver in itself. (Fig. 6.) Rf gain is fairly low to reduce overload in the broad-tuning stages, but there should be no difficulty in getting all that's needed in the 455 kc amplifier. There is a tuned rf stage, a mixer and separate oscillator, two stages of *if* at 455 kc, a diode second detector, a separate agc rectifier, and two stages of audio. Optionally, there is squelch and a BFO, with provision for manual gain control. Audio output power is enough for mobile use. Most of the parts can be found in the Lafayette catalog, or salvaged from defunct transistor radios. The tuning capacitor used was 365 mmf per section and had nearly semicircular plates, so that with the series capacitors shown, the low end of six is spread a lot, but the high end is still covered. Try and get a sturdy one, and mount it so that straining the case won't twist the capacitor frame.

If you have never built and tracked a superhet before, this is one heck of a time to start. The main idea is that two gangs of the variable capacitor tune circuits from 7 to 11 mc/s, while the third, in this case, tunes an oscillator from 6545 to 10545 kc, 455 below the signal frequency. The trimmers built into the tuning capacitor (if there are none, wire some 3-30's in) are used to make things come out on the high end, and the slugs in the CTC coils are used to put the coils on the right frequency at the low end of the range. Since the slugs move things by the same percentage at each end and the trim-



mers have about twice the effect at the high end as at the low end, trimming at each end alternately several times is likely to converge to the proper condition, where the circuits track all the way. It is very convenient to have some sort of signal generator or test oscillator on hand when doing this, but a grid dipper can be used as a makeshift substitute. The 220, 470 and 720 pf capacitors which are in series with the coils and tuning capacitors should be silver mica type, and within about 5 per cent of the right value. Do *not* use "BC" or "GP" type ceramics—in fact any ceramic capacitor that seems small enough to use is probably not good enough to bother with. Arco CM15's or DM15's come small and with excellent electrical characteristics.

In this receiver, AGC is applied only to the 7 mc rf stage and the first *if* amplifier. AGC on the 50-mc rf stage might help, but was not included. It is not desirable to cut the gain or collector current of the second

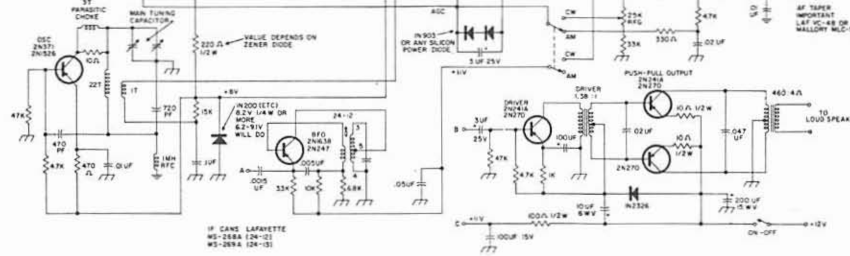


FIG. 6

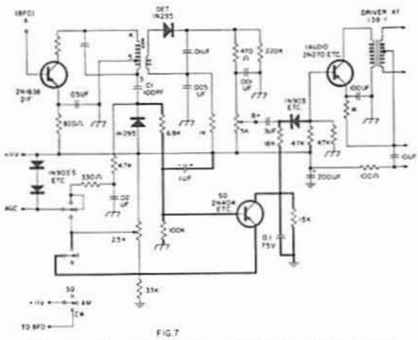


FIG. 7

C1 may be changed to 150 or 200 mmfd if strong locals still overload or block on AM.
Changes shown in heavy lines.
* RF gain in CW pos.—sq. in sq. pos.

if, as all the power it can deliver is sometimes needed. In order to get good AGC action with transistors, the last *if* amplifier must deliver enough power to the AGC rectifier to allow it to develop sufficient voltage to buck out the forward bias normally applied to the base circuits of the various rf and *if* amplifiers. For a 50 K ohm bias divider the required current is 12.6/50,000 or about 250 microamps. 250 ua through 5,000 ohms (4,700 plus 330) is 1.25 volts. The power needed is thus about 1/3 milliwatt under carrier conditions or 1.25 mw peak. If the last *if* stage is running 1 ma of collector current at about 11 volts, there is a maximum of 5 mw rf power output available class A into a 10K load. If one fourth of the theoretical maximum is needed to develop the DC for AGC use (assuming a perfectly efficient rectifier, which is not likely at one volt out) things are pretty thin, and we cannot afford to cut the collector current of the second *if* stage at all. If the taps on the last transformer are wrong, no signal, no matter how strong, will develop cutoff bias, and the receiver will wipe the modulation off strong local signals. If there is some doubt, feed the BFO into the last *if* input full strength and see if the emitter current of the first *if* (as measured by the voltage drop across the 1K resistor) can be forced to zero and beyond. The "beyond" is to allow for modulation peaks.

The control voltage in the absence of a signal is clamped by a couple of silicon diodes to about 1.1 volts forward bias. When the AGC starts working, the diodes unclamp, but the *if* voltage at the AGC rectifier has to be about a half volt before this takes place, that is, the AGC is "delayed." Any good silicon junction diode—power, top hat, alloy, diffused, or planar—will work here as the AGC clamp. The types suggested are small. The detector and AGC rectifiers are 1N295, similar to 1N34 but small and tested as a dectector.

When a squelch is used, it is desirable to set things so the squelch opens before the AGC starts to work. When the BFO is turned on, the AGC must be disabled, and to do this we shift the line to a manual gain pot. The clamps still function to limit the maximum-gain forward bias to a safe value.

The oscillator circuit is a modified Colpitts. It is not as easy to get going as a vacuum tube oscillator because there is not any amplitude-controlling mechanism in a transistor oscillator equal to the grid-leak-and-capacitor we are used to in tubes. Because the oscillator is around 7 mc, and a good oscillator transistor should be suitable for much higher frequency (so that the transit time, which varies with voltage and current and temperature, will be small compared with ninety degrees at operating frequency) there is danger of parasitics at higher frequencies, so a parasitic choke was put in.

As in the first mixer, the amount of drive is critical, and a bit of fiddling with the one-turn pickup coil (move it along the form to vary injection) will be needed. The oscillator runs on the low side with the values shown.

The *if* amplifier as drawn has effectively five tuned circuits. The Clevite TF-01A resonant emitter bypass has about as much rejection of off-frequency signals as another transformer. If you can't get one, use an 0.1 mf capacitor in place of it. The *if* transformers are small ferrite-core jobs, apparently U.S. made, which have an unloaded "Q" of about 140 at 455 kc. As the drift transistors have higher output impedance than the alloy types which were common when these were designed, we have our choice of more gain (by tapping the collectors up) or more selectivity (by using the former collector tap).

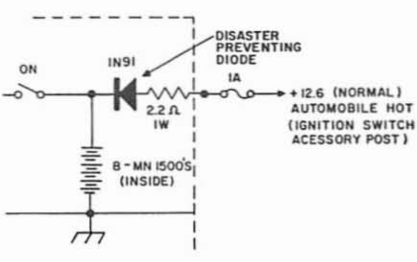


FIG. 8

We went for selectivity, except in the last transformer, which is heavily loaded by the diodes. Most 455 kc transistor *if* cans found in small six-transistor radios can be used in place of those specified; the connections are fairly standard. If more selectivity is needed, two coils coupled by a capacitor could also be used between the mixer and first *if*, with only a small reduction in overall gain. The coupling capacitor between the paired coils is run to the tap, so that a larger, easier to control capacitance can be used.

To align the *if* amplifier, a signal may be "stolen" from another receiver, by wrapping a wire around the last *if* plate lead in your HQ 129 or whatever, and tacking it to the base lead of the mixer in the transistor receiver. Tune the HQ 129 to a nice strong broadcast station and start twiddling screws. The single-tuned coils are just peaked for maximum output measured with a Simpson, etc. across the audio gain control (about one volt at most) and the double-tuned pair is adjusted by clipping about 100 mmf across the primary terminals of one can and trimming up the other, then moving the 100 mmf to the primary terminals of the other can and peaking the first.

The audio amplifier is conventional. It differs from most small transistor radio audio amps in that it runs on 12 volts and puts out half a watt rather than 9 volts and a quarter watt. The idling current of the class-B amplifier should be about 2 ma. Less gives scratchy quality, more uses too much electricity. The diode gives a no-signal bias which varies with temperature in the right way to compensate for the thermal characteristics of the output transistors. If a 1N2326 is not available any cheap alloy PNP transistor may be used, connecting to the base as cathode and hooking collector to emitter for anode. A small adjustment in the idling current can be made by changing the value of the emitter resistor in the first audio stage.

The BFO circuit shown will work with almost any alloy transistor, but the loading on the signal circuits will be a little less with the drift unit specified. Any interstage *if* transformer will work. The BFO is tuned to band center. No pitch control is provided.

If squelch is desired, it is inserted as shown in Fig. 7. The manual rf gain pot is used to set the squelch level, when that function is in use.

In the first model, one transistor was switched between BFO and squelch. The BFO was too near the front end of the receiver, and BFO harmonics were all over the dial. Segregating the BFO fixed this: in the photos the BFO assembly is tacked on above chassis. In the receiver shown in the photos, a transistor is in the squelch socket, but the socket is not wired.

A list of possible transistor types for the receiver is given in Table 2. The recommended types cost from fifty cents each for some audio types to about a dollar each for the 7-11 rf and two and a half for the hot six-meter rf stage. You may find something satisfactory in your pickle jars full of slightly surplus semiconductors, but it's not too likelv. The types used in Japanese AM (not AM-FM) radios will not be suitable. Required collector breakdown voltage is at least 20, and 30 is better.

. . . W1OOP

Table of Transmitter Transistor Types

A. Silicon NPN RF Power transistors

Oscillator: Some 2N697, 706, 707, 708 some 2N718, 753, 759, 760, 913, 914, 915, 916, 957, 2N834, 2N1338, 1505, 1506, 2297.

Doubler: 2N707, 708, 915, 1505, 1491, 2297. If modulated, may have voltage breakdown problems. 2N1506, 2N1492, 2N1493, 2N1342, 2N2218, 2N3118 should be O.K. modulated.

250-miliwatt final: 2N1506, 2N2876, 2N2631, PT531, TA2084, 2N1978, 2N3118. Nothing more than five years old.

1.5-watt final: 2N2876, TA2084, PT657.

NPN AF amplifier: 2N35, 78, 167, 169, 214, 388, 445, 634, 635 etc.

PNP AF driver: 2N43, 188, 241, 270, 396, 404, 407 and many more.

Modulator: 2N1172, 2826, 2827, 2N301, 176, 276, 342, 553, 554.

Table of Receiver Transistor Types

Converter-RF 2N1742, 2N2494, 2495, PADT-28, 2N502A, RCA 2N2873, Philco T 1694, 2N1177 (last choice)

Mixer 2N1743, 2089, 1177, 1179, 2N1745, 2N1517

Osc. 2N1744, 1743, 1178, 2084, 1517, 1745, 1868, 2N501

7-11 RF 2N2089, 1180, 1517, 2084, 2N384, 370, 2N1726, 1747

mixer 2N2089, 1180, 1517, 2084, 2N372, 2N274, 2N247

oscillator 2N371, 1526, others will work, may need changes in feedback.

IFs, 2N1638, 2N2092, any listed above, for RF or mixer

BFO almost any computer or drift transistor, 2N1631, 1637, 247, 274. Squelch-anything.

AF driver & af output 2N270, 241A, 188A 525, 2N43A 2N1413, 2N1924, 2N1192

Zener diode = 1N200, or any up to 1½ watts, 6.8 to 8.2 volts nominal.

Note on transmitter transistors: The types used are Silicon NPN. If suitable transistors are not available on a beg, borrow, or buy surplus basis, it may be advisable to consider using the Amperex 2N2786 PNP germanium unit, announced some time after these transmitters were built. (Amperex Electronic Corp., 230 Duffy Ave., Hicksville, N. Y. has report #S113 on how to use it.) The main disadvantage is that the 2786s we have tested had roughly 30 volt collector breakdown, so that AM at 12 supply volts is not practical. The proper solution is to use series modulation from a 12v supply, or NFM, or a collector supply dropping resistor, adjustable so as to set up for maximum collector voltage that the transistor will stand and still modulate properly. The Amperex report suggests that 2N2207's can be used in the driver stages. The driver transistor costs under two dollars, the 2N2786 under five. Carrier output level for AM would be about 140Mw. For NFM, about half a watt out could be obtained.

Six-Meter Solid-State "Peanut Whistle"

This rig contains a Superhet receiver to get the selectivity. The transmitter doesn't need much power, so that a simple transistor overtone oscillator, driving a class C final, was enough. The power output is about 300 mw. The modulator uses three transistors and has more than enough gain to use a crystal or ceramic mike.

The receiver is a double conversion superhet, with the first conversion crystal controlled, and using one of those Japanese six transistor portable radios for the second *if* and tunable oscillator. The use of the radio saves considerable time and money in the construction of a receiver. They have fairly good selectivity and sensitivity, an audio section, tunable oscillator, and some of them even have a tuned rf stage. The price of the parts to build one of them is considerably more than the cost of the assembled radio. They can be purchased new for about five dollars for a six transistor radio. This is just slightly more than the cost of the transistors needed to build one. Sometimes it is possible to pick up one with a damaged case for less money.

The converter uses three transistors. It has a tuned rf stage, an oscillator, and a mixer. The sensitivity of the overall receiver is better than one microvolt for a usable s/n ratio. The selectivity is about 10 kc at the 6 db points. While this is not the spectacular mechanical filter type selectivity that some people would like, it is quite a bit better than any super-regen, and about as sharp as practical in a hand carried rig with a 1:1 tuning ratio. The tuning is sharp, but not so sharp that a station can't be tuned in with ease, provided that a fairly large diameter tuning knob is used.

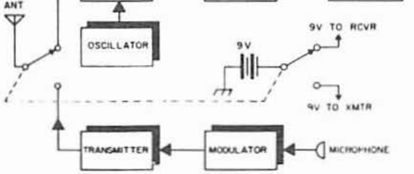


Fig. 1. Block diagram of the 6 meter transceiver.

The entire transceiver is powered by a single 9 volt battery, Eveready #2356 or equivalent. If space permits, six D cells will work. If you go hilltopping much, or are in an area where special purpose batteries are hard to come by, it may be better to use the flashlight batteries. At least you can get replacements easily. The Eveready #2356 or the flashlight batteries will work the receiver for several hundred hours if the transmissions are of a reasonable duration.

The rig can be built into a medium sized Minibox or any case that is handy. The one that I built was put into a case from one of the surplus "Gold Plated Specials" that have been available for several years at a reasonable price. There is enough spare room in the case for batteries, the rig and a recharger, if rechargable types are used.

Construction details

The easiest method of wiring, in general, is through the use of perforated boards with push-in terminals. Lafayette Radio sells boards made by Vector for reasonable prices, as well as the push-in terminals. A board 17" x 1³⁄₁₆" can be cut up to make all of the necessary boards for the transceiver and still have enough left over for several other projects. The board is cheap ($1.25).

The converter (**Fig. 2**) can be made on a board less than 3"x4", if care is paid to layout. The layout is non-critical with the exception that the oscillator should be kept away from the rf stage to reduce the possibility of spurious responses and images. By wiring both sides of the board, much space can be saved. The coils should be on the side of the board away from the chassis to avoid detuning when placed in the case. If space is at a premium, the miniature ¼" coil forms can be used but the number of turns will have to be raised to about nine or ten and taps adjusted in the same ratio.

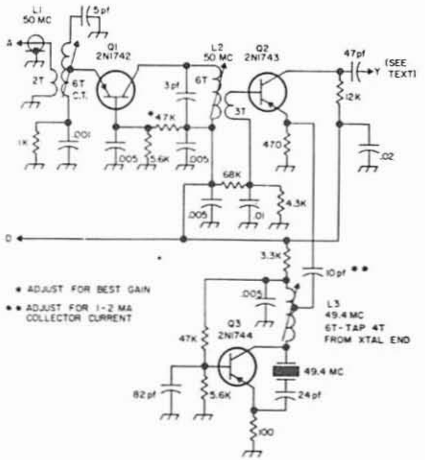


Fig. 2. Schematic of the 6 meter converter. Coils are on 3/8" slug tuned forms.

The transistors may be soldered in to the circuit if care is used not to overheat the transistor. A pair of long-nose pliers make an excellent heat sink. Tin the lead with a drop of solder, leave a small blob of solder on the junction to be soldered, and quickly melt the two blobs of solder together with a soldering gun or iron. This is the best method of soldering transistors, and is preferred to the conventional method of heating the entire joint to the melting point of solder and then applying solder, as the transistor is cooler.

Melt the solder, and if low melting solder (60/40 or 63/37) is used, it results in a good joint. Caution must be used not to make a cold-solder joint which can cause intermittents and related problems. More caution must be used not to melt the transistor as well as the solder. With a little practice (Use a ¼" resistor and practice making a few joints. You should be able to hold the lead ½" away from the joint without burning your finger. Best method for testing heat transfer to semiconductor device. A slightly warm finger can be cheaper than a ruined vhf transistor) you should be able to quickly solder transistors into the circuit without making a cold joint or overheating anything. Soldering is preferred to sockets in portable devices that may be subjected to a few jolts. They don't fall out of their sockets or cause intermittents due to poor contact if they are soldered.

The xtal used is a 49.4 mc third overtone type, available from any of the crystal companies.

There are many good transistors that will work in the converter. The Philco types are excellent, but a little expensive. I have found a good source of inexpensive transistors that work almost as well. The Sprague RT-82, which sells for about 60¢, seems to work as well as the more expensive types. It is an excellent general purpose vhf transistor and has countless uses in converters, transmitters, and lf amplifiers.

Transistors Unlimited, 462 Jericho Turnpike, Mineola, New York, is an excellent source of new transistors, diodes, tantilum and electrolytic capacitors, transformers, rf chokes, and many other parts at unbeatable prices. All of their merchandise is top quality and the prices are CHEAP! In a comparison check, six RT82's, chosen at random, were compared with a Philco 2N1742 as the rf amplifier in the converter. All of them worked as well, and there was no apparent difference in nf. Any weak station that could be copied with the 2N1742 could be copied equally as well with the RT82. A great deal for 60¢. In the final design, three RT82's were used in the converter. The other types mentioned were tried, most of them worked just as well, none worked better, all cost more. Design was based on the PxC equation, the transistors with the highest P (performance) with the lowest C (cost) were used, in keeping with the traditional ham design for the last fifty years.

Point Y (output) is connected to the BC receiver at the hot end of the variable capacitor tuning the antenna coil. This seems to work the best of any place tried.

The transmitter (Fig. 3) uses a RT82 as the oscillator, driving a 2N1143 as the final. The crystals used are third overtone type. There are no special layout problems. Just keep the output away from the oscillator and there should be no problems.

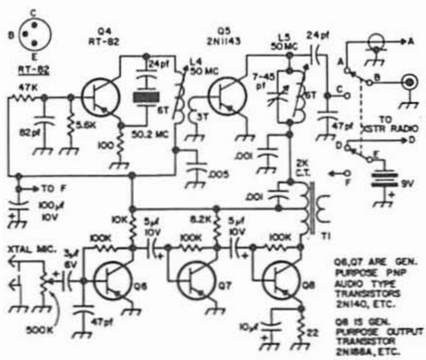
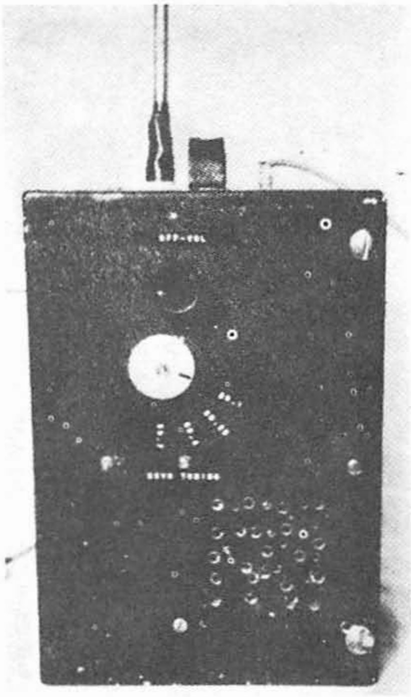


Fig. 3. The transmitter, modulator and basing of the RT-82's. Coils are 3/8" slug tuned forms.

The modulator can be built on the same board as the final. The general purpose audio transistors are the microphone preamp driving an audio output type transistor found in most portable radios. A 2N188A or GE-2 will work fine. The final is collector modulated through an autotransformer. I used a driver transformer with a 2000 ohm CT winding, applying the battery voltage to the center tap, and connecting the collector of the output transistor to one end of the winding and the collector of the modulator transistor to the other end.

The completed boards are mounted into the case with machine screw type standoffs, three or four being all that is necessary to mount each board. The transistor radio should be of the type that has the tuning capacitor coming out to the front panel with a directly driven shaft. Ones with dial cords are a problem to mount. The radio is removed from the case and the knobs are removed. The speaker leads should be removed from the speaker that is left in the case. The leads should then be removed and replaced with longer leads from the pc board to the new speaker. A 4" speaker works better than the ones that are usually supplied with the radios. It is preferable that the radio used have a positive ground (it should also be the type that uses a 9v battery for power) as it simplifies construction. The majority of the Japanese 6 transistor portables are 9v positive ground, but it should be checked anyway. If the radio is of the type that uses a volume control mounted on the back of the pc board, meant to be used with a knob that protrudes from the side of the radio, remove the control from the board, jump the switch connections, bring out three leads and replace it with one of the dime sized controls that mounts on the panel of the transceiver. A 10K type with a switch should work for most radios, and the switch can be used for the power switch for the rig. A shaft extension is brought out to the front panel (a long screw, of the same thread used to mount the control knob on the front panel of the case with two or three of the machine screw standoffs. The speaker is then connected to the leads connected previously. The power and ground connections are connected to the proper terminals on the tr switch. Be careful to observe polarities. The output of the converter is now connected to the "ant" connection of the variable capacitor. The other units can be interconnected, the battery mounted and wired, antenna connections made to the tr switch, etc. A DPDT switch works fine as a tr switch. This should complete the construction of the transceiver.



The transceiver as built in the Gold Plated Test Oscillator cabinet. Using a neater cabinet is permissible.

Tuning, final adjustments, etc.

Apply power to the converter and the bc radio. Tune the oscillator slug (L3) until the stage is oscillating (an increase in noise should be heard in the speaker). Connect an antenna or signal generator and tune L1 and L2 for maximum sensitivity. By tuning the antenna coil slightly higher in frequency than the mixer coil, it should be possible to get fairly good bandwidth from the converter. Peak the antenna trimmer in the bc radio for maximum signal near the center of the desired segment of the band. Take a small screwdriver and CAREFULLY tune the if transformers for maximum signal. On some radios, slight regeneration may be noticed when all of the *if* transformers are tuned to the same frequency. If it is severe enough to cause a heterodyne on all received signals, detune the transformers slightly. A slight amount of regeneration may be helpful in improving the sensitivity. With slight regeneration, the sensitivity may be as much as twice what it was when the *if* was stable, without affecting the useful nf of the receiver. This will require some experimenta-

tion to find the optimum amount. A weak signal will usually quiet the hiss.

Tune the oscillator coil of the transmitter (L4) until the stage is oscillating. Make sure that a dummy load is connected to the antenna (a 47 ohm resistor will do); then tune the final for maximum rf. Watching the S meter of a monitor receiver will tell you if the oscillator is working and when things are tuned for maximum. Turn the modulation control at minimum and connect the microphone. Slowly advance the control until modulation seems to be around 90%. The modulator has more than enough gain for a crystal mike, and the modulation control is necessary. Be careful about overmodulation as the final transistor can be damaged by high audio peaks. With the values given, there should be an adequate safety factor at 100% modulation. If the oscillation quits when the final is loaded or modulated, take a turn off of the secondary of L4 to reduce the coupling. This should complete the tune-up of the xcvr. Connect an antenna and repeak L1 and L5.

For portable use, a whip antenna such as the Lafayette 99 G 3017 will work fine. With the whip stations as much as 100 miles away have been copied Q5. With the beam, it seems to receive as well as my Clegg 99'er. The transmitter is good for working local stations and it is much fun to see how far you can work with a few milliwatts. It is amazing what can be done with such low power. It is also nice to know that you have a complete working transceiver that is all solid state.

With much careful searching of the junk box, the rig can be built for under $20 and for that price, it is hard to find anything that will work better or you can have more fun with. For those who are lazy, you can use one of the little printed circuit converters sold by Vanguard Electronics and save yourself the trouble of building the converter, although it costs somewhat more. I tried substituting the converter section with one that I borrowed with satisfactory results, although the one that I tried was one of their older models that I hear they have since improved. Replacing the 2N2190's with RT82's resulted in a considerable improvement in performance. There was no problem experienced with bc feedthrough with either converter. . . . WA2INM

Postage Stamp Transmitter for 6

You can really hide this one, even in the skin of a bear! It's only ¾ x ¾ x 1/8 in., is crystal controlled, puts out up to ¼ watt on 6 meters, and can be used for biological work, survival units, etc. With a 6 in. antenna I've heard it out to 15 miles.

It is amazing what can be done on VHF today with off-the-shelf subminiature items. Of course you do have to look hard for some of those shelves – but they *are* available.

The Crystal

As far as I know McCoy is the sole manufacturer of a suitable crystal less than 1/8 in. thick. McCoy has a special glass blower (from the Old Country?) who encloses the tiny little crystals in glass. These gems work, and work extremely well. I've even run 15 mW through the crystal itself and so far caused no trouble.

Figure 1 shows a sketch with dimensions of this jewel in its Type MM glass package. Of course they don't just give them away but where else can you get one 110 mils thick? There is still the next size up, the M20, with a "tin can" holder which is 183 mils thick, if you have the room.

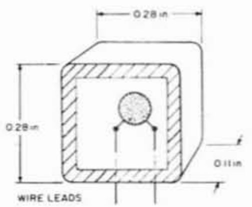
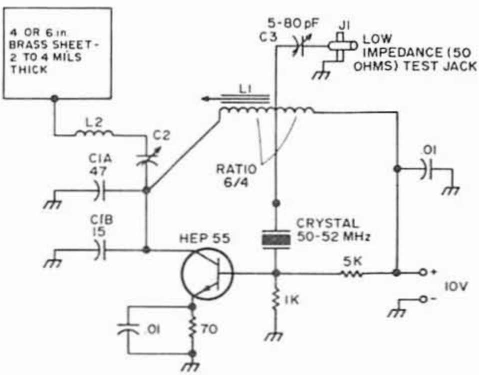


Fig. 1. McCoy's Type MM crystal is an incredibly small element enclosed in a tiny glass package not much larger than a thick-film capacitor chip. Less that 1/8 in. thick, the area of the crystal is about ¼ in. square.

Transistor

Just for fun you might say, I soon tried the Motorola HEP 55, but after checking against others of the same size or smaller, I stayed with it. After all, it's only $1.20, it is plastic, and can easily be filed down to the desired 1/8 in. thickness. The plastic takes up about a third of the overall thickness of these little powerhouses, so you can easily file down to .125, a little on



NOTES:

1. "Ground" is the copperclad baseboard plus the battery.
2. J1 should light a No. 48 or 49 pilot light bright.
3. L2 will vary with antenna size.
4. Check final tuning carefully with CIA and CIB compared to a No. 463 Arco mica trimmer, 10 to 180 pF.

Fig. 2. Even though the transmitter packs down in density to about the size of a postage stamp, the circuit is straightforward and without surprises for the builder.

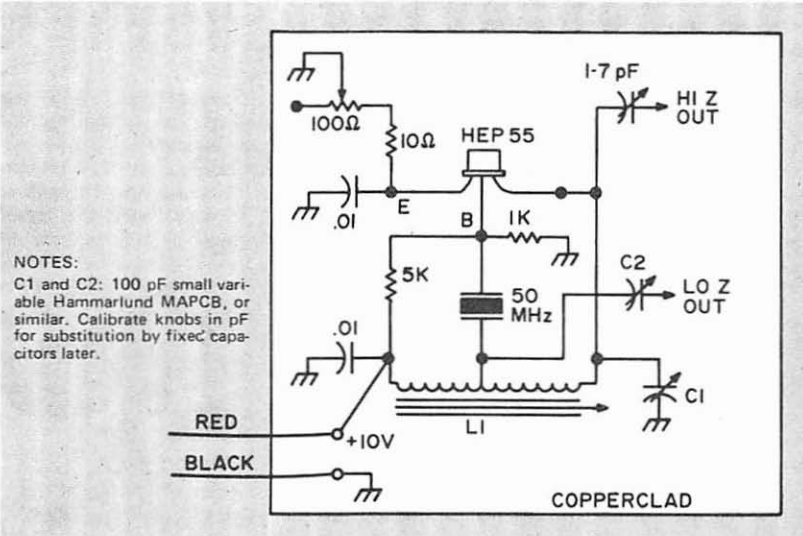


Fig. 3. Breadboarding the transmitter into a test configuration with regular-size component will give you the chance to get the "feel" of the circuit and its capabilities.

each side. We also checked out several dozen of them for "activity" in the circuit of Fig. 3. by grading them as *very good, good,* and *fair* About 10 were measured in the *very good* category. The rest go fine in i-f circuits, so that settled that question.

I have run 45 mA at 10V for hours at a time, getting over 200 mW output of rf with no trouble of any kind; so there's no need to fear pushing a little if you have a few extra on hand.

Coils

There are two coils, one of which is for loading the 6 in. antenna. Made by Piconics, a suburban Boston company, the coils are tunable and tiny (less than 1/8 in. thick). The tunable feature is one of the major advantages of these coils because, apparently, there are no variable capacitors in existence less than 1/8 in. thick.

Just to see what effect the tiny coil size had on the power output, we cut it down and kept cutting down until we reached the size of a piece of spaghetti about 80 mils diameter, wound with 34-gage wire. Even though it was squashed almost flat, the output power remained the same. When the circuit is properly tuned and loaded the coil really doesn't make much difference. Once again, the influence of the matched circuit and the loaded Q! If the proper amount and phase of feedback is there, which it is in this case, the rf output almost burns out a No. 48 bulb.

The circuit tunes broad but correctly and smoothly, and stays exactly on 50 MHz, or 50.4, or on whatever frequency the crystal is ground for. It also stays on the air, which is very important. As usual with any crystal oscillator, load it up to where it does go *off* the air, and then unload it so that it stays *on* the air with whatever battery voltage you may choose to use as the end of the battery life.

Breadboard Test

Use the test jig of Fig. 3 with large variable capacitors for tuning up and checking out the subminiature components *before* you mount and solder them into the tiny "chassis." I found that 15 turns of wire (32 or 34 AWG) with the crystal feedback tapped on at 5 turns from the low end is very good. Ten turns of 26 AWG on a threaded paper form is handy to start with, and sure-fire for use on 6 meters.

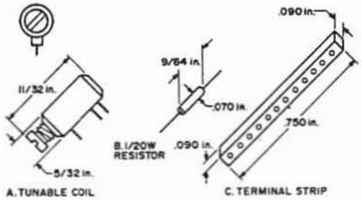


Fig. 4. Layouts and dimension of some of the "micro" components in the postage stamp transmitter.

If you calibrate the knobs on the variable capacitors you can then substitute fixed values later when you get down to the subminiature size, and do the tuning with the Piconics coil. This tiny wonder, shown in Fig. 4, actually has a core which moves in and out by means of threads in its nylon holder. Don't forget, you've got to tune *something*. It is possible to substitute fixed values of capacitors and make it work, but I'm assuming you've handled enough transmitters to know the value of tuning up. A good Piconics coil for 6 meters is the one labeled B121K713Y1 That's quite a mouthful, but it not only indicates the inductance but the ratio of the tap position as well – just be happy that someone makes one that's on the shelf ready for you.

Resistors

Sprague Electric, Nashua, N.H., makes good 1/20 watt resistors. They are precise and tiny, and they work. Figure 4 shows dimensions.

Capacitors.

Republic Electric makes capacitors up to the .01 μF value used here. They have a maximum diameter of 60 mils. That's under 1/16 in., in case you haven't been in a machine shop lately. Every one of these skinny cylinders has worked properly.

Mounting Strips

In many instances in the past we've made frequent use of .021 "common pins," brass, nickel plated, for terminal strips, hammering them into 20-mil holes in fiber glass strips or linen-base Bakelite. Well, these are too big for this job! So I cut up some of the linen-base Bakelite stuff into square cross-section rods and drilled through the sides of them, as in Fig. 4C.

Figure 5 shows the drilled strips, or "logs," with a small strip of 1½- or 3-mil fiber glass under it for security against ends of components or wires shorting to the base plate, and examples of components used. You can drill as many holes as you have wires or solder two or more wires together on one side of the strip.

Chassis

Figure 6 shows the baseboard cut out to receive the major components, which are the coil, the crystal, and the transistor. As these units are over 100 mils thick they cannot be mounted on top of the baseboard but do very well in the cutouts with coil cement or other types of embedment added later. Although I am showing one example of a circuit with the 1/8 in. thick technique, you can of course use the same method for other circuits. I have gone up to 432 MHz with this type of construction, so various things can be done at the 1/8 in. thickness. After mounting and soldering, you can also use high-temperature coil wax for a test unit which you might want to change later. This can also be used for a "next to final" model.

Batteries

In my quest for a really tiny battery (1/8 in. thick), I found that only two qualified as "desirables," and one of these was ultimately eliminated by testing. The two candidates were the *silver oxide* and the *mercury* types. The dimensions of the smallest is shown in Fig. 7. For up to about 100 mW output, with a battery drain of about 20 mA at 10V, a check was made on the above types. The silver oxide battery lasted 30 minutes and the mercury battery 65 minutes. Of course, these tiny power sources are *not*, absolutely *not*, sold for any such use. In fact, the engineering department heads of the two largest bat-

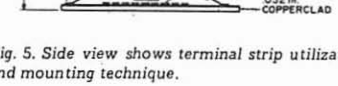


Fig. 5. Side view shows terminal strip utilization and mounting technique.

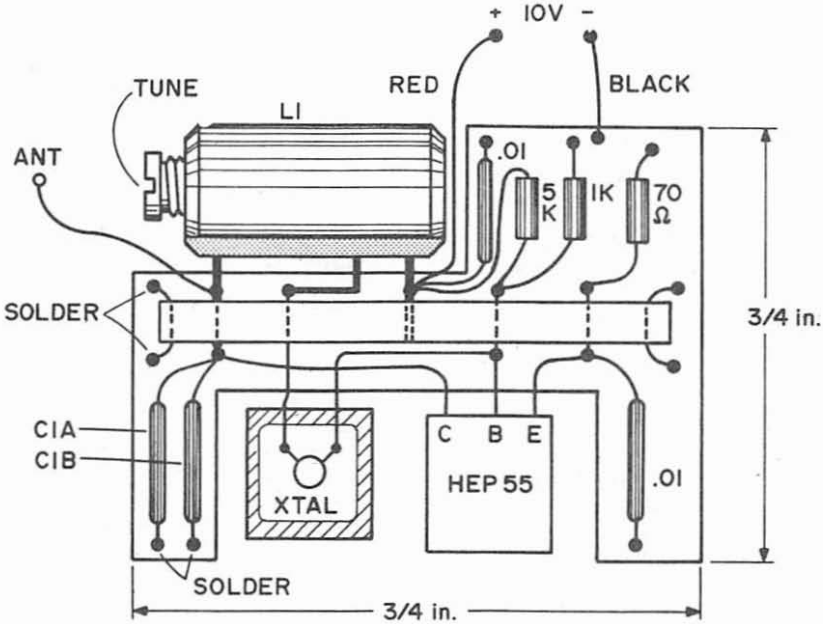


Fig. 6. Blowup top view shows layout of subminiature oscillator. Actual physical size of unit will be 3/4 in. square.

tery companies tend to either raise their voices or hang up the phone, or both, when they find out what you really want out of their little aspirin pill batteries.

There are two immediate solutions: reduce power, or reduce the time on the air. For some uses – such as continuous monitoring with voice or other sound modulation – you have to reduce power for any reasonable life at all. This can be done very simply by using less battery voltage or increasing the resistance of the emitter resistor, or both, and a slight amount of retuning. For some other types of uses, such as biological tracking, hidden transmitter hunts, etc., you can turn the rig on for short periods only; for example, 10 msec out of every second for an increase in battery life of *better* than 100 times. (There is nothing worse for battery life than a constant heavy drain.) This type of automatic keying is, as usual, another story. The tiniest little transistors, the Microtabs by GE, can be used for this service in a multivibrator circuit to drive another one of them in a simple on–off switch type of hookup.

For the battery pack, a 1/16 in. sheet of soft plastic such as PVC (polyvinyl-chloride) can be used to hold the batteries in a pack of four. six, or eight (or even ten if you like "high power") as shown in Fig. 7. If you order a large quantity, Mallory will *weld* tabs on each pill-size battery and you can then solder them together to make up a pack. Count on no more than 1.0V per cell, regardless of the drain you may expect, because they will soon enough reach this level, or even lower, unless you operate in a pulse mode.

For test operations we did solder leads onto them, much against the advice of the engineering departments of the battery companies. So far, no ill effects, but you have to do this *very* carefully. We used a 25W iron well cleaned and tinned, shined up the battery case first, and then tinned it. A touch of perhaps less than one second does

the trick, also using very-small-diameter solder. I am *not advising* this method, just mentioning that I did use it! Also, use flexible subminiature wire such as multiple strands of 34 AWG, for example, with Teflon insulation. These batteries can be purchased where hearing aids are sold and in many radio stores. Naturally, use the largest size you can put into your project. The "aspirin" size will only give a life of 12 mA-hr at something like a 1 mA drain – *not* enough to operate the oscillator. It will run at around 4 mA, though. This power level is easily adjustable by the emitter resistor, as mentioned before. You can generally expect about 50% efficiency for dc input to rf output power with the circuit shown in Fig. 2.

Circuit

When I first made up this design I was looking for a foolproof crystal circuit, one that would not take off on any frequency other than the one marked on the case. The circuit shown achieves this goal; after working with it some time, I find that it can be a very powerful oscillator as well – stable and reliable.

How it works

Referring to Figs. 2 and 3, when the collector is tuned to 50.4 MHz, for example, by C1 and L1, with 10V in, a volt or so on the base, a bypassed resistor from the emitter to ground, and a 50.4 MHz crystal connected between the base and the tap on L1, it *will* oscillate. It's a law of nature! Note that the feedback looks as though it was degenerative, or negative. It only looks that way though, because the crystal reverses the phase of the feedback voltage going to the base. This is a fact of life very difficult for some engineers to swallow but it works!

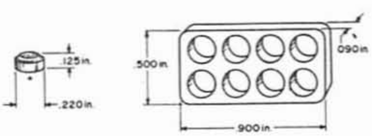


Fig. 7. The tiny battery can be used with other batteries if a holder is constructed from PVC as shown here. (Holder shown accommodates eight batteries.)

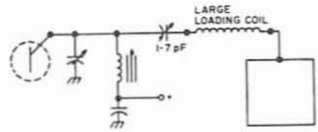


Fig. 8. Although several antennas and loading techniques were tested, the approach shown here proved significantly superior.

The result is advantageous. With positive feedback coupling, the oscillator can be quite critical for the right amount of feedback, tuning, and loading. With negative feedback coupling, it will only oscillate when the crystal reverses the phase, which of course occurs only on its proper and marked frequency. Just how many half-waves of sound are standing across the crystal is the concern of the manufacturer, as long as these sound waves inside produce 50 MHz electromagnetic waves on the outside, and vice versa of course.

Crystal Power

I think this is a matter to be decided by usage because, while the makers talk about 2 or 3 mW of power in the crystal circuit, I found that a small pilot bulb in series with a 50 MHz crystal lights up a little on the 1W oscillator. In the CW mode you will not run that much, but with pulsing you may well go over it. About 10 to 12 mW is required in the transistor base–crystal circuit for about 500 mW out at the collector circuit. You can see that the gain of the transistor is important also.

Antenna

The tiny 6 in. antenna's performance is a surprise. I used the antenna and loading circuit shown in Fig. 8 On 6 meters, this is an antenna of about 1/36 wavelength long. The only disadvantage of the antenna loading technique shown is that you need close to the right number of turns on L2; other loading techniques may be less critical, but experiments have shown that they are not as efficient when it comes to rf radiation.

Receiver 1

First, you need a diode field strength meter for use at a fixed distance, say a foot or so to start with, in order to tune up and compare radiated power.

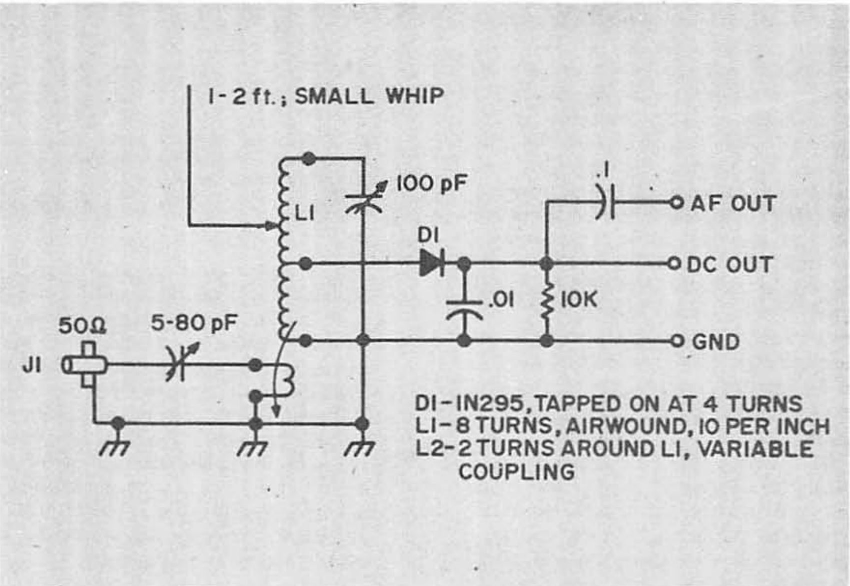


Fig. 9. A diode detector makes a convenient and useful receiver for checking the performance of your postage-stamp transmitter while it's on the bench.

The best setup was another short antenna clipped onto the diode detector's tuned circuit about halfway up the coil (Fig.9). For meter indication at maximum distance, the length of the whip and its contact position along L1 are important.

Figure 9 shows the circuit we used, which is also a good frequency meter for checking to see if you *are* on 50 MHz and not on some harmonic. *Never* rely on a high-gain receiver for this basic fact. Use it to check for noise, hum, stability, etc. once the frequency has been determined.

Polarization can also be checked with the diode receiver by using a regular 50 MHz dipole (or beam if you can handle it physically) across the room, or outdoors if needed, with its matched cable plugged into J1 (Fig. 9).

Receiver 2

We put some tone modulation on the rig to identify it because at a distance of 15 miles I wanted to be *sure*; but of course you can use plain CW with a bfo if you like. Either way, the signal comes in great with a regular receiver and beam on 6 meters.

For a particular purpose we can build up a good hand-carried receiver for use with these little rigs. This is a semi-fixed-tuned job with small knobs on the tuning capacitors for test purposes – it tunes over the band in great style. The front end has a 1.7 dB noise figure, which is very useful because you can take it to absolute "hermit" locations, where such performance really *counts*. . . . K1CLL ■

List of Component Manufacturers

Transistor: Motorola HEP 55
Coil: Piconics, Tyngsboro, Mass.
Crystal: McCoy Electronics, Mt. Holly Springs, Pa.
Capacitors: Republic Electronics Corp. 176 E. 7th St., Patterson, N.J.
Resistors: Sprague Electric, Nashua, N. H.
Insulation: Insulating Fabricators, Inc., Watertown, Mass.

Low-Cost 2-Meter Linear

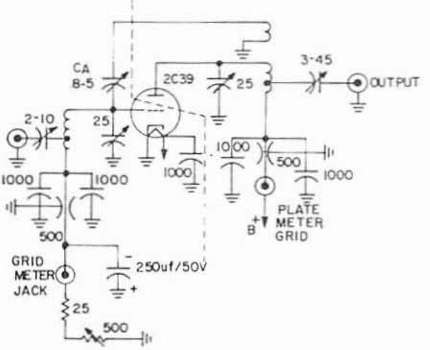
There are several new features in this linear for the Two'er which we trust will be of use to the developing amateur who is still struggling to acquire his education. An excellent triode tube is available surplus, at prices beginning around $4.50. It is also available new in quite a few different versions, specs, and prices, because it is a really unique kind of tube.

After getting this tube, all you need is some copper-clad bakelite, a few small capacitors, phono or UHF jacks to suit your cable connectors, and a home-brew power supply, as from an old TV set. You do not have to modify the Two'er in any way. Just plug the Two'er rf output cable into the rf input jack of the linear, using the microphone and modulator of the Two'er. Plenty of details follow.

VHF Neutralization

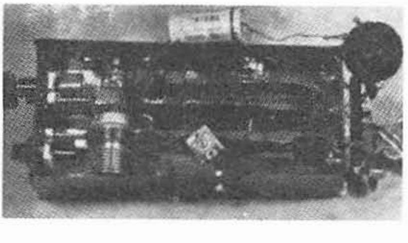
Plenty of excellent reference material for hf neutralization is available but the handbook writers begin to hedge as soon as they go up past 30 megacycles. They are also on relatively easy ground with the $20 double-pentodes for VHF, but when it comes to something inexpensive, simple to build, and powerful, where are they?

So we find ourselves today with practically nothing about triode neutralizing for VHF in the amateur handbooks. This in spite of the fact that there is a 100 watt triode with a transconductance of 24,000 micromhos with full ratings to 2500 megacycles, that you can buy for as low as $4.50 surplus.



What does the old reliable RCA handbook have to say? No help there either.

Plenty of dope on how to neutralize an amplifier that is already built, and a few words on neutralization in general, triodes and pentodes, but nothing on VHF. What gives? Are some people that determined to sell $20 pentodes to lads who just cannot lay out that kind of dough?



Let's look in Bill Orr's VHF Handbook. Plenty of real good dope in there on lots of VHF problems. A good 3½ pages entitled "Analysis of neutralizing circuits". Starts right in with a tetrode tube. No mention of triodes there. Further along in the book under "The grounded-grid rf amplifier" we find "One of the undesirable characteristics of the conventional triode rf amplifier is that the stage must be neutralized to prevent self-oscillation". "As the frequency of operation is raised the stage becomes increasingly difficult to neutralize . . .". Then there are several paragraphs on the advantages of the grounded grid amplifier. No diagrams are shown of a simple grounded cathode VHF neutralized triode stage.

One more handbook: "VHF for the Radio Amateur", by Frank C. Jones. At least on page 5 there is a picture of my favorite, the 2C39, and some other UHF tubes. He starts right in

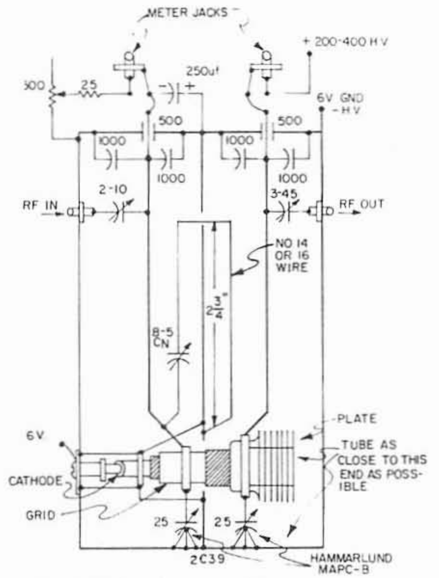


Fig. 1. 144 mc linear amplifier.

on whole circuits for transmitters, beginning at 50 megacycles.

He carries 144 mc into a pair of 4CX250B's, tetrodes, which is fine, but way out of the price range at present. At 432 megacycles he gets to the 2C39 tube and says ". . . it will function effectively if driven hard by the exciter." This is in a grounded grid circuit, and is just one of the disadvantages of the grounded grid. He makes no mention of any neutralization, relying on the "grid-separation" circuit to keep out self-oscillation. Which is ok but does not allow small drive power, as from a Two'er.

Well, so much for VHF neutralization in the amateur type handbooks. Now where do we go?

The 2C39 Tube

Let's see what this tube is like. It is the first tube in the "RCA Transmitting Tubes" technical book series. That's just a numbering accident, but makes it easy to find. "May be used to 2500 mc at full input", this book says. That should cover 2 meters all right! Then we see on the third line "Transconductance equals 24,000." Going back to the ARRL "Radio Amateurs Handbook" for the definition of transconductance, we find "The best all-around indication of the effectiveness of a tube as an amplifier is its grid-plate transconductance." "Transconductance is the change in plate current divided by the change in grid voltage that causes that plate current change" with fixed plate voltage. The transconductance of some comparative tubes follows: 2E26, 3500; 832, 3500; 807, 6000; 6146, 7000; 829, 8500; 6969, 10500; 6CL6, 11000; 417A, 24000; 6897 (2C39 type) 24800. The only tube that is in amateur use I know of that has a greater transconductance is the 416B gold-plated triode, a special receiving or low-power transmitter tube, at some 30,000 to 40,000. (when new!)

Bear carefully in mind though, that a 2C39 must be used in a *grounded cathode grid drive* circuit in order to use that Gm of 24,000.

Connections

The next thing special about the 2C39 is the connections. No pins, no leads. Just *surfaces!* While cylindrical cavities are fine and a real must around 1296 and up, you can get along ok on 2 meters with properly used trough lines. Using a one inch strap for the grid and plate conductors (one for each) or lines, you can cut out a semi-circle in the end of the strap, see Fig. 4, and get a large area connection right onto the plate and also the grid, through, of course, the flexible ring connectors with fingers which are also large area.

What does this do for you? As an example I quote again from F.C. Jones Handbook, "The 6146 is not too efficient at 144 mc." "This tube has to be neutralized by series tuning the screen grid lead inductance . . ." His circuit shows a 4 turn plate coil with series tuning, as in a half wave circuit. now look at the 2C39 circuit in Fig. 1. Parallel tuning, high Q, and how is it tuned? With a 25 mmfd capacitor between plate and ground. And what does it do? At half power capability (50 watts) it lights a 25 watt bulb to full brilliance, when driven by, of all things, a standard unmodified Two'er! It appears that almost any of the 2C39 "family" works fine on 2 meters.

Fig. 1b. Box detail. All copper clad bakelite inside.

B.I.O.N., today, after many years of VHF and UHF and even microwaves, we VHF-UHF amateurs do not have the proper tubes to work with! As you can see from Fig. 1, the grid and the cathode have to "go through each other" to get where they belong. Admittedly, the 2C39 was not designed for grounded grid service. But what else have we got that will do the same job at anything like the price?

I like pentodes too, but not at $20 for the budding young VHF-UHF lad. He's still got to build his power supply. At least with this rig he can step up from a Two'er to 30-40 watts. More with a blower.

Circuit Detail

Basically there are two trough lines: one grid line and one plate line, with a common ground wall in between. This wall has two holes in it, one for the tube, the other for the neutralizing circuit. Electrons flow from the grid to the plate through the first (inside the tube of course), and reversed phase electromagnetic energy (*not* electrons) comes back to the grid through the second hole.

Tube connections may be made with surplus rings, fingers, straps, or "sockets". See Figs. 2 to 5.

The 6 volt filament "plug" in the small end of the tube can be bolted to an insulating plate of bakelite which in turn is bolted to the wall of the cavity. This will hold the tube in place pretty well. Figs. 2, 3, 4, and 5 show some rough details of the connectors

FIG. 2

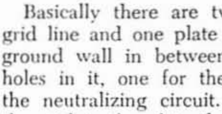


FIG. 3

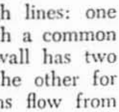


FIG. 4

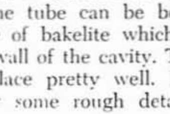


FIG. 5

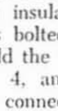


Fig. 2. Filament plug.
Fig. 3. Cathode ring connector. These fingers turn in onto the cathode.
Fig. 4. Side view of grid connector ring and tube end of grid line.
Fig. 5. Plate ring connector. These fingers turn back on the plate ring.

that I used. These are obtainable from the Instrument Specialties Co., Little Falls, N.J.

The whole rig appears to be a "natural" for rf grounding. A bypass on the 6 volt connector made no difference. Using one inch copper strap creates a high Q for several reasons. First, there is plenty of copper surface for the electromagnetic momentum to work on, and second, this copper is "in line" and protected from radiation by the trough line. Granted a cylindrical cavity where all rf paths are equal length, with 100% shielding, is better, but the effort is not justified on 2 meters. Look what you're getting as is! The Q is so high now that large capacitors in parallel can be used to tune to 144 megacycles. High C is of course a standard way of getting rid of parasitics, harmonics, etc., but generally not possible on VHF. It is possible here though, and does a good job. It also makes available low impedance input and output circuits for 50 ohm cables.

The one inch strap lines are grounded for rf at the far end of the trough lines with feed-through capacitors. I didn't have a high enough value so had to add on more discs. Again, not critical. Just don't bypass modulation out of the plate line. That is, in case you wanted to have more fun and use a high-level modulator on the tube later on. As a linear of course, there is no modulation across those bypasses. This is a downright unique feature of this amplifier, it is really uncritical throughout. You can do almost anything to it and it still keeps on working.

The tuning capacitors are Hammarlund 25 mmfd units. They have an additional grounding strap soldered to the rotor spider. It is possible that with a blower and 600 volts, the plate tuning capacitor should have a bigger spacing. We'll check this unit out for the full 100 watts and perhaps a high level modulator to go with it later. Right now it does very fb as a linear.

Neutralizing

If a line (piece of heavy wire in this case) is introduced into the plate tank circuit, grounded at the plate end and open at the other end, it should pick up and produce energy out of phase with the plate voltage on the tube. It does! This out of phase voltage is sent through the common wall to the neutralizing capacitor Cn which is just about the rated grid-plate capacity of 2 mmfd. That is, the Cn is about .8 to 4 mmfd, and the setting used looks like 2 mmfd. To set this neutralizing capacitor, plug a tuned rf power detector into the plate circuit output jack with the 2C39 filament turned on and plate volt-

age off, with the Two'er feeding rf (all of its ¾ watt) into the grid circuit. The neutralizing null setting is immediately evident and effective. Remove the detector and plug in a 15 to 25 watt bulb, turn on the plate voltage, 200 to 400 volts, and tune up. With the circuit dimensions as shown you may get some self oscillation but only when you tune the plate circuit near 200 mc. When it's all tuned up and loaded even this disappears. After neutralization as per above, grid current does not vary at all, not even one black lines worth, when the plate is tuned through 144 mc. What more do you want?

Blower

For higher power, if desired, some small holes in the far (cold) end of the plate trough line with a small blower attached and a piece of plastic or cardboard over the top of the trough line should allow plenty of cooling. In fact, the air could be sent through the grid trough line at the same time. Some would circulate anyway through the tube hole.

Operation as a Linear AM Amplifier

Here is where this little powerhouse shines. As a rugged low-cost, non-critical triode, in a highly efficient amplifier, it allows very easy tune up. In fact it should work immediately. It did for me. Granted an AM linear is quoted as being "not quite" so efficient as a class C amplifier but what does this difference amount to anyway? RCA transmitting tube handbook says "The efficiency varies from approximately 33 per cent for an *unmodulated* carrier (who needs one) to 66 per cent for a fully modulated carrier." You want more than 66% efficiency on 2 meters? It will cost you a little more in money, time, and effort.

New Gimmick Dept

We claim a first here (until someone shows up with a copy of Sleeper's Radio, 1932, with one in). This is the use of grid rectified bias for a linear. The simple gimmick is a large, really large capacitor, of several hundred mfd (not mmfd) across the grid resistor. This provides the "stiff" bias recommended for use with linear service, and needed. Without it you get downward modulation. With it you can get upward modulation and the difference in audio is quite noticeable. I checked many times, here, and on the air, between battery bias, (ideal) and the one shown in Fig. 1, and so far no one has been able to detect any difference.

Incidentally the 2C39 grid is so designed that no protective bias is needed in case of excitation failure (such as the Two'er stopping operation). Be careful of this with other tubes. Some, like the 811 types, are so designed that they take very little mils when not biased. Other tubes will run away and that's that. So in this circuit the cathode is grounded both for rf and for dc. Without bias of any kind, the 2C39 takes about 90 miles at 400 volts on the plate. With 500 to 600 it may need a little protective bias.

Cable Matching

With the circuit as shown, matching between the Two'er and the linear amplifier is pretty good. You may have to retune the Two'er plate output circuit, in combination with C1 and C2 for maximum grid mils. We found around 20 to 30 grid mils, with a maximum of 40 without any grid resistor. Do not run the amplifier that way. After preliminary tune-up, recheck the neutralization. Do this also after final plate tuning In fact, do it several times. Gradually all adjustments, Two'er tank, C1, C2, C3, C4, and Cn will come into line. This is recommended in the handbooks incidentally. It is also the natural way to do it.

Switching

For the moment we will leave you on your own with switching ideas. A good antenna change-over switch has been rebuilt for use on 432 mc and works good there, so it has to work good on 2 meters. An ordinary porcelain wafer switch was taken apart and a "ground plane" of copper-clad bakelite installed very close to the back of the wafer. RG-58/U cable is cut close and installed on this ground plane also. A simple possible diagram of send-receive switching is shown in Fig. 6. This is with 2 switches to throw. A more automatic job (one switch to throw) would put a sensitive relay ($1.95 Radio Lafayette) in, or on, the Two'er, controlling an exterior relay on the amplifier.

. . . K1CLL

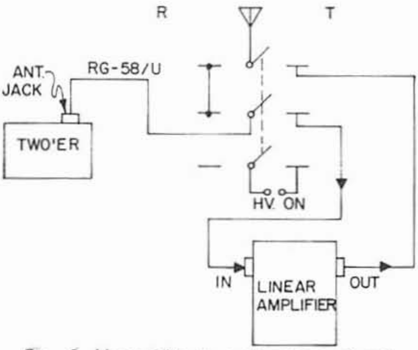


Fig. 6. Note: This is a temporary circuit that requires both switches to be thrown.

Two-Meter Solid-State Walkie Talkie

You can get a real boot out of this. Practically as many schools of thought as there are writers. Some make no mention whatever of neutralization. Some do. Some speak of unilateralization. Don't let that 17 letter word bother you. It just means that transistors have resistive nuisance feedback as well as capacitive nuisance feedback and you have to "neutralize" both. That's "unilateralization." For the time being for amateur rigs forget about the resistive part. Be happy if you can neutralize the capacity component.

Now to get to the point. Setting up our good transistor, it's got to be good for two meters because it is listed as a 1000 megacycle amplifier, oscillator to 2000 mc."

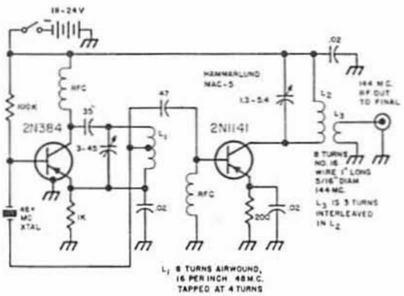


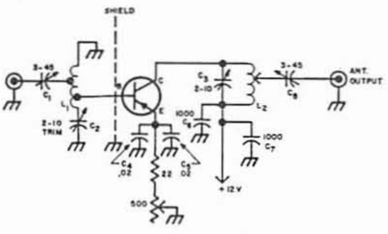
Fig. 1. Two meter driver.

Fig. 1 shows the crystal oscillator and tripler. Until further notice the little transistor with its milliwatt power and low voltage can be considered as not pushing the 48 megacycle rock around. This does not mean you can put in a VHF power job as the oscillator unit with maybe 100 volts and 3 watts. The 48 megacycle crystal might just not like that.

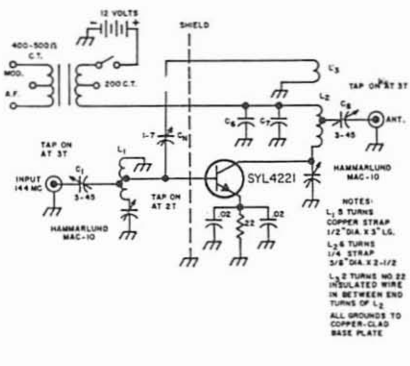
Fig. 2 shows the rf final test set. Note the bare simplicity of it.

For neutralizing first I tried a 2 meter tuned circuit capacity coupled, loosely, between the collector and the base, also trying it between the collector and the hot end of the base circuit. This gave the first real sign of life to the rf output as the 180 degree out of phase energy attempted to cancel out the internal feedback capacity of the transistor. It did work fair, but was touchy, and of course would be strictly a single frequency affair.

After due deliberation we came up with the neutralizing circuit of Fig. 3. At least it works. You can of course see the resemblance to a more or less standard neutralizing circuit. The inductive coupling is low impedance and readily adjustable as to amount, by varying the number of turns, or their placement, or both. It also leaves the rest of the collector circuit as is. It's hard enough to get a decent handling collector circuit on 2 meters without hav-



Above. Fig. 2. Trial circuit. Transistor should be shown as NPN. Fight. Fig. 3. Final circuit.



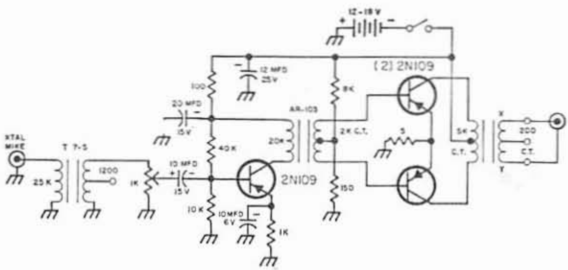


Fig. 4. Modulator.

ing to put in neutralizing taps, ungrounded tuning capacitors, etc.

So now we have variable inductive coupling for low-impedance neutralizing. The reverse phase is easily obtained by turning this coil over, in case you had it wrong at first. Just remember the old "blooper" rule, with a plate coil and a grid coil wound the same way near each other on the same coil form, put the plate on one end, and the grid on the other. That's for an oscillator with 180 degrees out of phase grid-plate operation. It is also the way to neutralize if you use just the right amount, in an rf amplifier!

Also remember that more plus voltage on an npn base makes the collector go more negative, like a grid and plate, so the same rules hold for a grounded (or common) emitter stage.

Adjustable low-impedance (simply because it is large) capacity coupling is used over to the base, Cn in Fig. 3. And it can be arranged to be quite suitable for 432 megacycles.

With this neutralization the amplifier stage works fine on 2 meters. Lights a no. 49 bulb brightly. Looks almost like quarter watt out. But don't do it that way. Tried it out on a little 2 over 2 beam hung on my rotator mast below the 432 14 element Yagi. Carrier went 25 miles or so. QTH here only 100 ft. above sea level. See later tests also.

Note the assorted bypasses on the emitter and collector returns. The 500 ohm variable in the emitter lead can be left out as it stays mostly at zero. The collector mils run between 10 for a 12 volt battery, to 20 miles for a 24 volt battery supply. But, to repeat, do not modulate it that way!

Note also the copper strap inductance with six turns parallel tuning on 2 meters!

Modulation

The modulator itself is just straight af work, on which plenty of real good dope is available and published. The problem is just what to do with that audio when you get it. Here, as mentioned, I simply modulated the collector voltage by inserting a modulation transformer in series, like with tubes. And promptly burned out a whole mess of good UHF 2,000 mc transistors. Just so it doesn't happen to you, this is what took place. In trying out various modulation transformers (and transformers, period) some of which had nice labels like "16 ohms", "48 ohms", etc., I assumed that there wouldn't be too much af voltage on such low ohmage secondaries. Was I ever wrong! Incidentally I was using a single large audio transistor and a carbon mic. in this first modulator. (Not shown). The first time I laid the mike down on the bench, Ping!, out went the transistor, shorted out from collector to emitter. Before I got wise and put my VTVM on the modulation transformer secondary and found as much as 50 volts of af, several more went out! Add that 50 volts to the 24 collector volts dc that I was using, and no wonder. So, too late wise, but still better than never at all, I dropped the collector voltage back down to 12 volts, dc, and kept my eye on the ac modulator voltage before switching on the collector. And while talking also! Since then ok. Just another item about transistor work. Iope it doesn't happen to you.

On the Air Tests

As I "tune up" a modulator I listen in on a tuned crystal detector, transistor af amplifier, and earphones, the kind with the big ear pads on them. This is pretty good for a start. You can compare modulation nicely with your regular rig if you have one. Of course, this doesn't tell the whole story. Like FM, overmodulation, etc. It does check reasonable fidelity of speech though, and distortion is heard right away. I have heard plenty of lads with

rf-af feedback who should have been listening to their carriers!

The vital check of course, is to go over to a friend's house and "hear yourself as others hear you." The first time I did that I changed modulators in a hurry. The final one shown in Fig. 4 works OK. It also uses quite standard parts and will get you on the air walkie-talkie. On your beam at home it will also surprise the heck out of you and your buddies on the band nearby! It is kind of an eerie effect, going on the air with such a rig for the first time. Someone calls you and you look over your shoulder to see who it might be that he's calling. Soon your confidence grows though, and you're talking like you had 100 watts instead of 100 milliwatts. . . . K1CLL

144-MHz Transistorized Converter

The antenna filter is built in a massive type of construction in order to obtain very high Q circuits so that the loaded Q will be only a small fraction of the unloaded Q values. If the unloaded Q is perhaps 1000 and the loaded Q is 25, the circuit loss will only be 2.5% per circuit or 5% for two circuits. This would mean about .5db loss in noise figure which is low enough for good dx reception in a quiet location with a good antenna. The transistor converter shown here has a noise figure of a little under 2db which with the antenna filter adds up to 2.5 db. If the coax antenna feeder has a loss of from .5 to 1 db, the net NF amounts to 3 to 3.5 db which is far below the more usual 5 to 10 db NF of the average VHF station. Even a good parametric amplifier and antenna feeder system is seldom more than one db better than the transistor converter shown in **Fig. 2**. 144 paramps are very narrow band units and only function into and out of resistive loads. Any regeneration in the converter rf stage, or change of SWR in the antenna system with rotation of the beam or due to weather changes can make a paramp into a real monster for oscillation instead of amplification. Good ferrite "isolators" to tame a 144 mc paramp cost nearly as much as a radio receiver.

Fortunately, new economical transistors are being made available which are better than vacuum tubes for rf amplification at 144 to 148 mc. Each year brings forth some new transistors which are better, and at the moment there is one priced near 50 cents, the TIXMO5, which makes even a good paramp system unattractive for dx reception. In time transistors may reach down near the one db NF which can be used for moon bounce or satellite amateur signals.

These high angle received signals are less troubled by man-made noise if the antenna system has very low side and back lobes of response. Even on reception along the horizon of 144 mc signals it is better to hear external man-made noise than front end receiver noise. Some operators feel that there is no advantage in getting the receiver NF below the man-made or atmospheric noise level. However, this writer doesn't agree since the human ear is a good differentiator of signal to variable noise level, being able in some cases to reach well below the 0 db signal to noise ratio. Man-made power buzzes, auto ignition and appliance electrical noises and atmospheric static crashes are not too much like the hiss of receiver noise, which means that good *if* noise blanker systems and noise limiters in the radio receiver can be of real service in reception or radio signals. All this means that the VHF amateur should strive for a good low NF in his receiver system.

The converter shown here has a low NF, measuring from 1.7 to 2 db over the range of 144 to 147 mc. Since present day low priced transistors overload easily, out-of-amateur-band strong commercial stations can produce the effect of spurious signals within the amateur bands. This effect is more noticeable in a low NF converter. A good antenna filter ahead of the converter tends to eliminate this problem as long as the signals are not within the pass-band of the filter. The filter shown in **Fig. 1** consists of two tuned circuits, slightly overcoupled, so as to produce a pass band of from 2 to 3 mc with close to 50 ohms input and output terminations. The circuits were made large physically in order to have very low losses and a secondary benefit was obtained. The filter is very effective in preventing spurious signals in the transmitter from getting into the antenna. Both lower frequencies from the exciter stages and harmonics of 144 mc are greatly attenuated in this filter which helps meet FCC requirements. The losses are low enough and the voltage ratings high enough so full legal power may be run in the radio transmitter

The filter shown in **Fig. 1** was built into a 4 x 3 x 17 inch aluminum chassis and cover. A center shield with top and bottom grounding lips separates the two tuned circuits and the 3 by 3 inch cut out at the low rf potential end acts as the aperature coupling between circuits. This was started as a 2 inch cut out and the coupler used from 143.95 to 145 mc originally, then trimmed out in steps to 3 inches long for bandspreading the filter to cover from 2 to 3 mc width. Each tuned circuit consists of an aluminum plate line 16

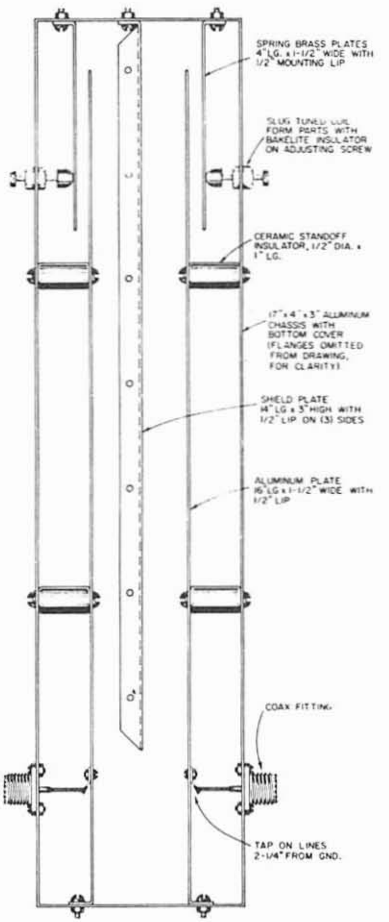
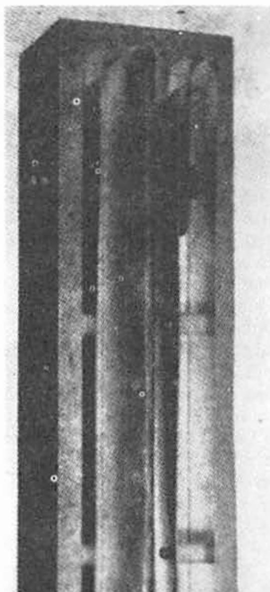


Fig. 1. Two meter antenna coupler-filter. This drawing is one-third size.

inches long and 1.5 inches wide supported by an additional .5 inch right-angle lip for grounding and by two ceramic insulators as indicated in the sketch of **Fig. 1.** The tuning capacitors at the "hot" ends consists of pieces of spring brass 4.5 x 1.5 inches in size with .5 inch grounding lips. All grounding lips and mounting areas were sanded to get bright clean contacts and each grounding lip was fastened to the chassis with three machine screws. These grounding areas must have very low resistance in order to keep the circuit losses down to a minimum. Copper lines and shield box would provide less loss than aluminum, especially if the filter had to be made more compact in size. The spring brass tuning capacitor plates are adjusted by means of spare slug coil form mountings with a .5 by .5 inch bakelite insulator threaded onto the adjusting screw and epoxy glued to it also. These adjusting screws were mounted about 3 inches from the ends of the 17 inch chassis centered on each 3 inch side. At the opposite end, coax fittings were mounted and tapped into the rf lines 2.25 inches from the grounded ends. Lots of self tapping screws were used to ground the center shield to the chassis and to the bottom cover, and the cover to the chassis. This cover was 5 by 17 inches in order to use the extending sides for mounting the filter up on the wall above the antenna relay.

Two meter converter

The converter was built on a piece of copper clad board 2 by 6 inches in size for



Two meter antenna coupler-filter.

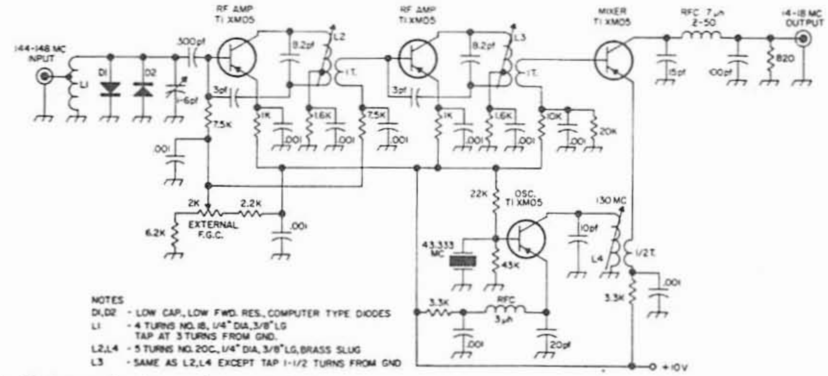
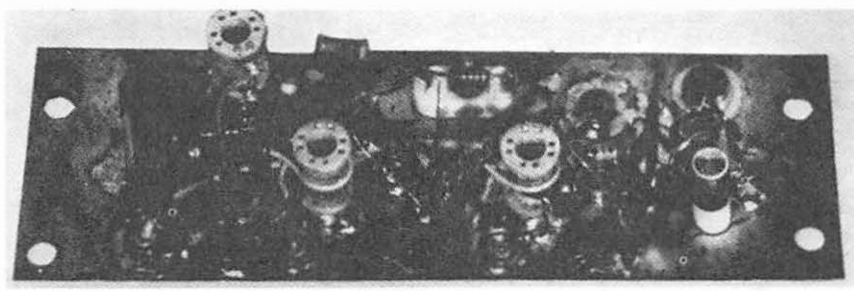


Fig. 2. Low noise two meter converter.

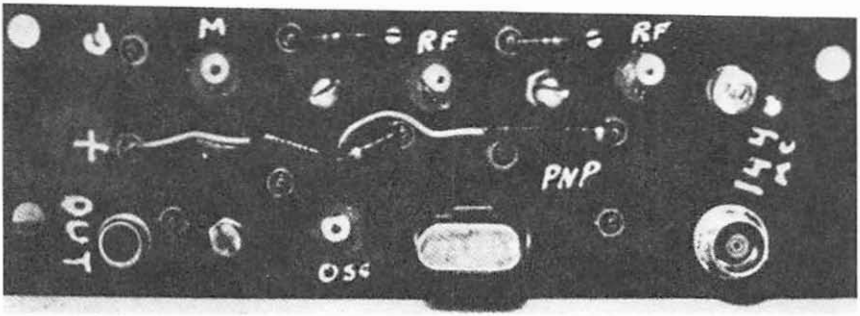
mounting into a 6 x 17 x 3 inch chassis along with numerous other converters and a switching panel for *if* outputs and battery connections. The chassis completes the rf shielding of each converter which is needed to prevent direct pick-up of signals in the 13.95 to 19 mc *if* range. Double shielded small coax lines to the *if* receiver also are advisable. The double copper braid on some types of coaxial line is worth while unless these shielded converters are mounted within the shielded cabinet housing the *if* receiver.

The Texas Instruments TIXMO5 transistors are marvelous rf amplifiers, mixers and oscillator-multipliers. The only problem encountered was breakage since these units had plastic housings which were brittle, and broke easily when the transistors were pushed into the large transistor sockets shown in the photographs. Later some smaller sockets were purchased which overcame this problem since they were designed for TO-18 sized transistors, but had the disadvantage of costing a great deal more than the TO-5 sized sockets. Fig. 2 shows the circuit and values of parts used in the converter. White color coded ferrite slug coil forms of similar size may be used for slightly better Q values with 4 turn coils (and 1 turn taps) in place of the brass slug forms shown.

Two rf amplifiers with fixed neutralization were used with only one tuned circuit between stages since the antenna filter added a great deal of image suppression. The input circuit is a low Q (loaded) design in order to provide a low loss resistive termination to the antenna filter. This resulted in a NF of less than 2 db when a noise generator was connected directly into the coax input jack of the converter. The transistor protective back to back diodes across this input coil added about .1 db NF loss but was deemed worthwhile for protection against an antenna relay isolation deficiency when using a high pow-



Bottom view of the two meter converter described.



Top view of the two meter converter

ered transmitter. Low forward resistance diodes with low shunt capacitance are needed for this purpose. Type 1N100 diodes were used here, but better diodes are available. Don't use the old "standby" IN34A diodes in such a low impedance circuit such as shown in **Fig. 2**.

The mixer stage uses base input and emitter oscillator coupling with large enough bypass capacitor values to give a low impedance even at the *if* frequencies. This avoids the need of series tuned (at 14 to 18 mc) circuits shunted from base and emitter to ground. The mixer collector circuit has to be of low Q design in order to cover 4 mc bandwidth. The pi network of **Fig. 2** meets this requirement and fixed values of capacitors and inductance may be used to obtain a center frequency of about 16 mc to cover from 14 to 18 mc. The values shown provide a mixer load impedance of about 2000 ohms or more, with an output impedance of 50 or 75 ohms for connection to the *if* receiver.

The 43.3333 mc overtone crystal oscillator has an emitter circuit resonant about midway between the overtone and fundamental crystal frequencies. This insures oscillation at the overtone frequency only and permits the single transistor to provide 130 mc output in the collector circuit for coupling into the mixer stage. Transistors other than TIXMO5 may require a different value of emitter capacitor than the 20 pf shown since this value regulates the regeneration at the 130 mc output frequency. Less efficient transistors require smaller values. The small 3 μh rfc in this emitter lead must resonate with the small emitter bypass (20 pf or so) at some frequency above 15 mc but below 43 mc. Resonance below 15 mc will cause the overtone crystal to oscillate at its fundamental and introduce a strong signal into the *if* receiver tuning range. If this effect is present use a smaller inductance such as an Ohmite Z144 rfc of 1.8 μh. Too small a value of capacitance from emitter to ground may cause oscillation near 130 mc not crystal controlled. Too large a value will cause less output at 130 mc than is needed for good mixer conversion gain. Too much oscillator voltage injection into the mixer is undesirable so a value of coupling link should be chosen to provide a little less than maximum mixer gain and noise. All of these adjustments interact to some extent so some experimenting is desirable if optimum results are to be obtained.

In locations where there are other two meter ham stations, an rf gain control is needed, which is external to the converter. This is a type known as forward gain control since the current in the transistor is increased to reduce the gain. This requires a collector resistor and rf bypass capacitor which reduces the collector dc voltage fast enough to cause a gain reduction as the current increases. Forward gain control is many times better for overload and cross-modulation reduction as the transistor gain is reduced as compared to the more usual current reduction-gain reduction circuits used in many transistor rf and *if* designs. By the same token, forward automatic gain control (FAGC) in transistor *if* systems is highly desirable. With PNP type transistors FGC of the type shown in **Fig. 2** causes a collector current increase and gain reduction as the potentiometer is moved to a less positive voltage setting. The values of limiting (fixed resistors) and potentiometer values can be chosen to give optimum gain control for nearly any type of transistors. The total resistance across the battery supply can be of values such that the

battery drain is somewhere between ¼ and 1 ma in the main control unit. The transistor base current (microampere values) is then negligible in figuring resistor values. These values should be such that the transistor collector current in each rf stage varies from about 1 ma at full gain (or lowest NF) to about 3 ma at reduced gain and 1 volt or so across the collector to emitter.

. . . W6AJF

Compactron 2-Meter Transmitting Converter

The success of the six meter crystal-VFO transmitter described in Chapter 14 suggested that the same type of system might be very useful of two. So we built one using Compactron tubes to go with the six meter exciter. It has worked very well. The block diagram, **Fig. 1**, shows how it works. The left section is the exciter from the six meter rig. The next part is the heterodyne mixer to two meters. Then comes a 5763 buffer amplifier and a final 7984 Compactron with the modulator from the six meter rig.

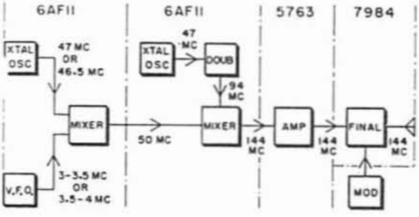


Fig. 1. Block diagram of the two meter VFO rig. See test for explanation.

A description of the converter circuit

Fig. 2 is the schematic diagram of the exciter. The first triode section of the 6AF11 is used as a 47 mc crystal oscillator. Regeneration is used to increase the output, the ease of starting, flatten the power-output curve on the capacitor and make the circuit less critical.

The output of the oscillator is fed to a doubler which is the other triode section of the 6AF11. The 94 mc output of the doubler is fed to the control grid of the pentode section of the 6AF11.

The 50 mc output from the six meter exciter is fed to the screen grid of the pentode mixer. This is screen grid modulation. Note the 50 mc link-coupled tuned circuit L5-C3 which couples the six meter rf to the tube.

The pentode mixer plate is tuned to 144 mc. Output from this mixer will burn out a number 48 pilot lamp (120 mw) if the plate voltages are pushed a little. However, I wanted a stable signal so used only 80 volts on the oscillators and added an extra stage of amplification to increase the drive to the final.

The power amplifier

Now that we had a stable low-level two meter signal, we began looking for a good Compactron power amplifier. The TV horizontal output tubes were tried first, but handled very poorly at VHF. That came as no surprise since they're designed for 15.75 kc, not 144 mc.

But a little bit of looking turned up the General Electric 7984 Compactron designed for mobile and fixed communications transmitters. It is capable of delivering a power output of 46 watts at 175 mc! There is a slight hitch, though. It can remain slight depending on your attitude toward $5 tubes and how long you expect them to last. The rating is for *IMS.*

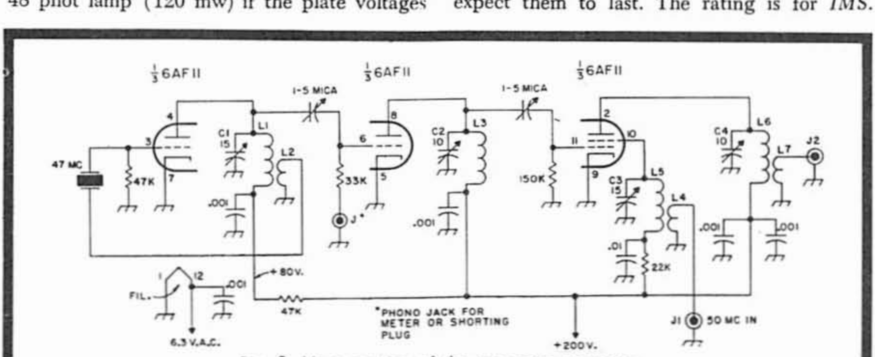


Fig. 2. Mixer portion of the two meter converter.

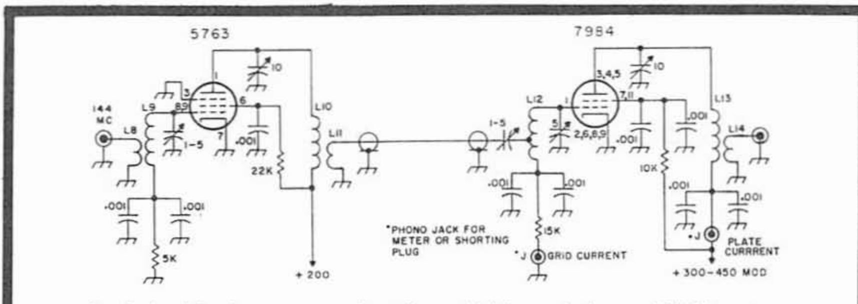


Fig. 3. Amplifier for two meters. Don't forget shielding and other good VHF layout.

That means Intermittent Mobile Service. That is an application where the design factors of light weight, minimum size and "exceedingly high power output" are the primary requirements even though the average life expectancy of the tube may be reduced.

Please note that I am not recommending 46 watts out all the time—unless you want to buy a new tube every so often. We *have* lit a 60 watt bulb to full brilliance on two, but normally run it on the air at a modest 60 or 70 watts input. It really lights a 25 watt bulb, giving about 30 to 35 watts out.

The manufacturer also published ICAS ratings. They suggest a 56 watt maximum input. So take your choice. The whole idea of a variable tube life based on power input is very interesting.

So much for input. The 7984 has the 12 pin Compactron base. Comparing it to the 6146, the lack of a phenolic base on the 7984 allows half inch shorter leads. The larger diameter also means greater spacing when needed and more connections per element. In **Fig. 3** you can see the many connections to each one. It makes a big difference on two. The spacing between grid and plate pins is enough to permit high power without any need for neutralization at all. Incidentally, the tube has a 12 to 14 volt filament.

The amplifier circuit

Fig. 3 shows the amplifier circuitry. Note that the first stage is a 5763 buffer. The reason for this was explained before. This stage runs very cool, but makes it possible to have a real stable signal. The extra tuned circuits help keep down the TVI, too.

The final stage is the 7984 power amplifier. Even though this tube, like more high gain beam power tubes, has a very high input capacitance, I was able to use a parallel tuned tank and still get excellent efficiency. Drive is about two or three mils through the 15 k grid resistor. Input to the 7984 is about 150 to 175 ma at 450 volts. We would advise you to use a lower voltage for tuning up.

The modulator uses two 6L6GC's and was described with the six meter rig.

COIL TABLE

L1: 7 turns, 16 tpi, ½ in. dia.
L2: 5 turns #22, ins. inside L1
L3: 4 turns, 8 tpi, ½ in. dia.
L4: 2 turn link in L5
L5: 7 turns, 16 tpi, ½ in. dia.
L6: 2 turns #12, ¾ in. OD, ½ in. long
L7: 2 turn link near cold end L6
L8: 2 turn link over L9
L9: 2 turns ¼ in. copper strap, 7/16 wide, 1 in. long
L10: 3 turns copper strap similar to L9
L11: 2 turn link over L10
L12: 2½ turns copper strap
L13: 2½ turns copper strap
L14: 2 turnli nk

. . . K1CLL

Compactron 100-Watt 2-Meter Linear

Here is a transmitter for two meters which can put you well out of the 2E26-6146 class. Two 7894 Compactrons can put out 100 watts on two with high level modulation.

Considerations

Some interesting thoughts occurred on VHF transmitter design while working on this rig. Push pull has been used for VHF for well over 30 years, and ever since the pre-war days the general design for medium power tubes has centered around the double beam power tube with plates on the top and one glass bottle. Examples of WW2 tubes of this type of course are the 832 and 829. Since then a nice new series of this same type (5894, etc.) have come along. However, they are generally expensive and require a fancy socket.

Today we have a new family of single ended tubes, real toughies, with ratings to 80 watts input on 175 MHz. These are the Compactron transmitting tubes with

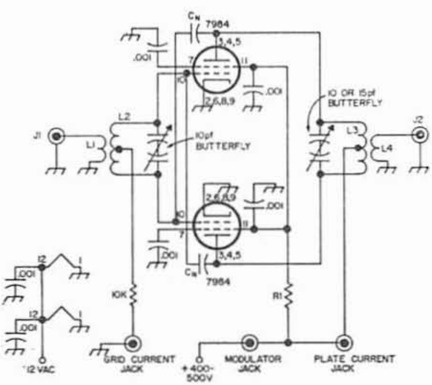


Fig. 1. Schematic of K1CLL's Compactron push pull final amplifier for two meters.

television priced 12 pin sockets that are intended for single ended use. However, as you will see, when you do put them together in push pull, they go like two outboard motors on a racing hull.

Fig. 1 shows the schematic and Fig. 2 the pictorial layout of this amplifier using push pull 7894 beam power Compactrons. Each costs $5.00 and the pair is rated at a dc input of 162 watts in IMS (Intermittent Mobile Service). However, if you run this much power, expect to change tubes every now and then. If you don't want to change tubes every so often, then run 125 to 150 watts input to the two tubes.

Make sure that the two plate lines are the same length and that the grid lines are also equal in length. The neutralizing wires and tabs should then cross over each other and be similar as well.

Solder all eight cathode leads to the chassis, bypass the heater and screen leads with small flat disc capacitors, and you're ready to start "strapping." You can use coils for this type of circuit, but if you have room, lines are preferred. The push pull grid lines showed the usual improvement in length of inductance over the single grid type.

We obtained 7 mA ot grid current through the 10-kilohm grid resistor, dropping to 4.5 mA when the screen and plate power was applied. Naturally some of the electrons which previously landed on the grid are now attracted to the screen and plate by their positive voltages. You should expect that the grid tuning will flatten out a little too. It will!

We tried both small and large size butterfly tuning capacitors on the plate lines, and both worked equally well. For arc-over security, I went back to the larger size.

The neutralization was easy after one or two tries. First we set up an elaborate little brass shield with large holes, subpanel insulator and nice long pins to carry the neutralizing wires through the shield from the grids to the plates. However, we had to go to the shortest possible heavy copper wire, about number 14, directly across

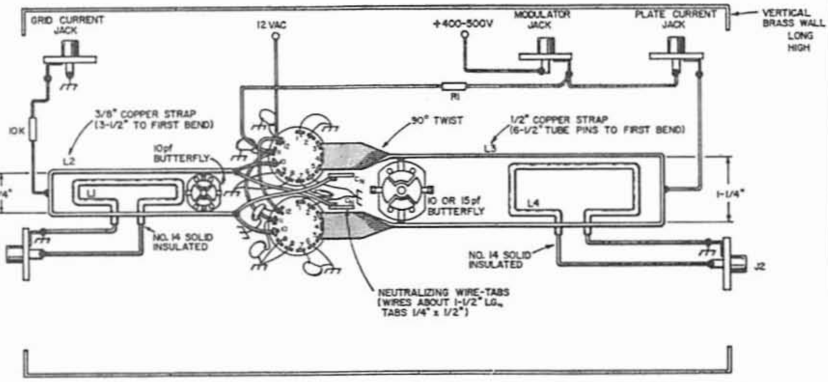


Fig. 2. Layout, coils and details of the two meter Compactron final. This drawing is one-third size

the socket from grid one to plate two, etc. Putting 200 mA of plate current and no rf drive on the other tubes, the proper capacitance is easily found by watching for self oscillation with the plate and grid circuits tuned to 144 MHz. The ½ by ¼ inch tabs ended up about ¼ inch from the plate lines. These tabs are really over the plate pins where they are soldered to the strap lines. Using insulated sticks, move the tabs nearer or further away from the plate lines and you will soon find the best place for both wires and tabs. The tabs, to be more explicit, are over the first ¼ inch of the plates lines. Half of each plate pin is bent over so it presents a flat surface to be soldered to the strap, and right over these points and about ¼ inch away are the neutralizing tabs. After the neutralization is completed, there should be no self-oscillation at any point in the 144 to 148 MHz range.

A plate dip of almost 70% was obtained with this amplifier. The pencil arc test with the plate dipped gets pretty hairy with 160 watts input; we would recommend that the pencil be taped onto a dry wooden stick and that the other hand be kept in the pocket. The arc is at least half an inch long. When this plate circuit is loaded it will brilliantly light a 100 watt bulb on two meters. You can use either loop coupling or direct to the 100 watt bulb porcelain socket for a dummy load. We tapped the socket onto the lines about 3¼ inches up from the cold end for maximum loading.

Baluns

Note that the input to the grid circuit has an unbalanced to balanced transformer in it. This is a perfectly legal type of balun and works quite well. Just for a check we inserted two chokes and capacitors in each grid to check the grid currents separately and with considerable satisfaction we found them both to be exactly 6 mA. Note that inasmuch as we put in another 10 kilohm grid resistor, we now have 5 kilohms for the two grids. Actually the grid resistor turns out to be very non-critical.

We tried coupling the exciter to the grids capacitively and by a link, but both methods provided practically identical results.

The final total grid current (both tubes) through the grid resistor was 7.3 mA with no high voltage on, and 6 mA with the high voltage applied. The screen voltage was 135 volts with the plate loaded to 100 watts dc input, and 80 volts with the plate dipped. In that condition fewer electrons land on the plate and more on the screen; probably a little better screen regulation is called for.

The grid bias voltage, developed by the rf drive across the grid resistor, was minus 58 volts with the high voltage turned off, and minus 44 volts with the high voltage on and 100 watts of load.

That's about it except for modulation. Theoretically we need 80 watts of audio to properly modulate the 160 watts dc input. Our standard modulator with a pair of

6L6GC tubes seems to be good for a maximum of 55 watts of audio, so either four 6L6's or a pair of 7894's will do the job. Also, two 807's or a pair of 1625's can put out up to 120 watts. You can see that we're skating near the point where everything gets quite a bit more costly, with 1200 volt power supplies, 811A modulators, big modulation transformers, etc.

. . . K1CLL

144-MHz FET Converter

The 144 MHz band sometimes has enough nearby stations to cause trouble in receiving on this band. Very strong local or line-of sight transmitters can overload the usual transistor converter and ride in on top of the desired signals even though far enough removed in frequency so the selectivity of the main if system should eliminate this effect. Usually the trouble can be traced to the converter transistor mixer stage since perhaps 20 millivolts of signal will produce cross-modulation on top of the desired signal. The answer in most cases is to use an FET type as the mixer since it takes ten to twenty times as much input to show cross modulation. FET devices are usually better than nearly any type of tube mixer at vhf.

FET (field effect transistors) have been very expensive in the past but now some are in the one dollar class such as the TIM12, a plastic-cased transistor. It works very well as a mixer at 144 MHz but is not too good as an rf stage. The converter shown in the photographs and in the circuit diagram was originally built with two FET TIM12's in it, one as the rf stage and the other as the mixer. The noise figure measured about 5 dB which isn't bad for average local station reception but isn't good enough for 144 MHz dx signal reception. The TIM12 is a p-channel germanium FET unit sold by Texas Instrument distributors.

The rf gain and NF varied greatly at 144 MHz though these same units gave excellent results at 50 MHz in an rf stage. Apparently at 144 MHz the TIS34 FET (at 4 times the price) would be needed and it is an N-channel silicon transistor requiring a change in battery supply polarity.

It was decided to use a neutralized TIM10 vhf transistor (approximately 50 cents) in the rf stage, and oscillator, and the low-

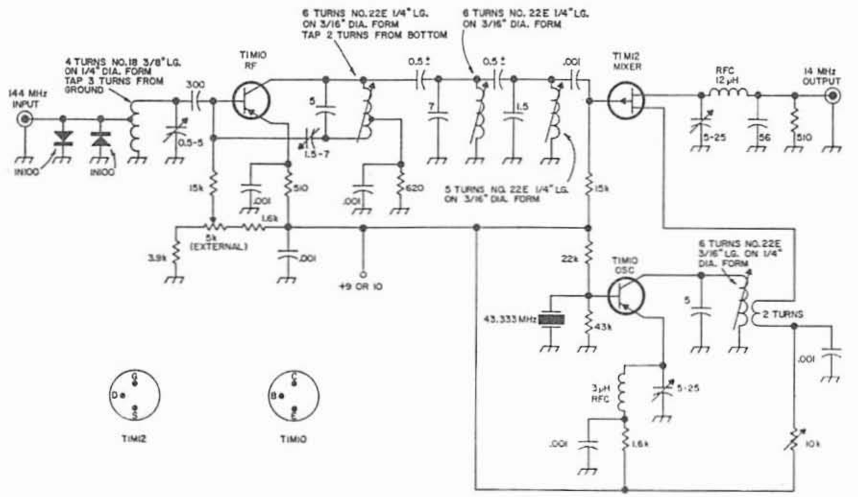
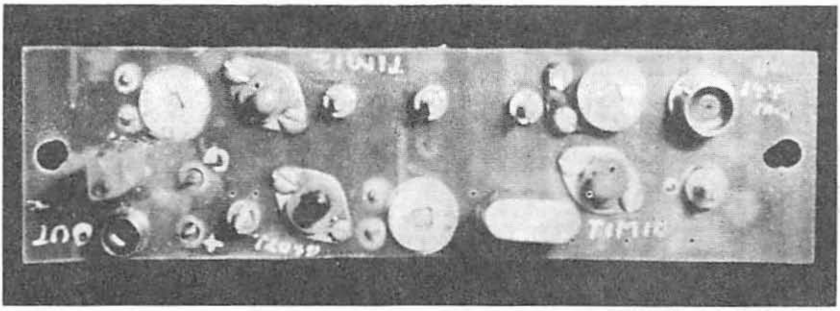


Fig. 1. Schematic of W6AJF's low cost, low noise, low cross-modulation, two meter converter. Note that only the mixer uses an FET; the mixer is responsible for most cross-modulation.

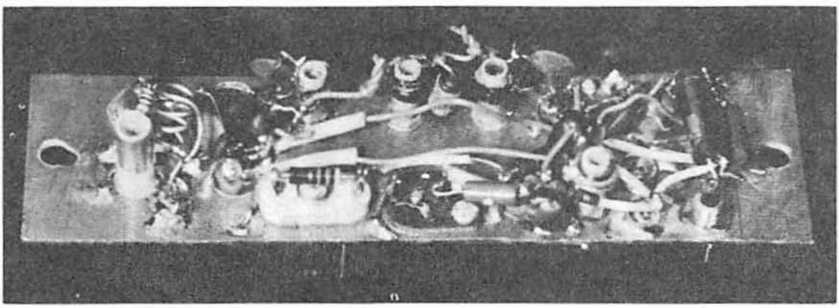


Top view of the converter described in this article. It's built on a $1\frac{1}{2}$" x 6" piece of copper-clad board. The copper is on the underside.

priced FET as the mixer. The resulting circuit is shown in **Fig. 1.** The NF measured at 2 to 3 dB which is fine for dx reception. Two 144 MHz signal generators were connected together thru a 10 dB pad (50 ohms) and the tone modulated generator also tied into the converter directly. The unmodulated signal generator was adjusted to 145 MHz and its output attenuator set to give an S-6 signal into the converter and if system. The tone modulated signal generator was then set to 144 or 146 MHz and its output increased until some tone could be heard riding in on top of the "cw" signal at 145 MHz. With maximum rf stage gain and maximum mixer gain, it took about 25,000 microvolts to cross modulate the S-6 desired "cw" signal. By increasing the mixer source variable resistor to 2-kΩ ro 3-kΩ the "tone" signal had to be increased to 50,000 μV or 50 millivolts. If a local signal is greater than that, some benefit can be obtained by using forward gain control on the rf stage. For extreme cases of cross modulation, a TIS34 N-channel FET stage (neutralized) would be desirable in place of the PNP ordinary TIM10 transistor.

Just changing the mixer stage from a TIM10 or other types of vhf transistors, to a FET mixer such as a TIM12, improves the cross modulation characteristic by at least 20 dB.

Type TIM12 FET's look like the TIM10 ordinary units but have a different basing arrangement as shown in the new circuit diagram. The 10-KΩ variable source resistor was not used in these modifications. Only the fixed 3.3 kΩ former emitter resistor was used in the source lead with an .001 μF bypass and two turn pick-up link to the oscillator coil. The gate is a fairly high impedance even at 144 MHz, so should be connected to the top of the tuned circuit instead of thru a one turn link as with an ordinary transistor mixer. Note that the FET



Bottom view of the converter. The "gimmick" capacitors between the three tuned circuits are about 1/2 pF apiece. They should be adjusted for best coverage of 144 to 148 MHz.

unit only requires one resistor to the plus supply voltage rather than the voltage divider normally used with ordinary transistors.

The overtone crystal oscillator uses a low-Q emitter circuit tuned above the fundamental frequency of the crystal (about 14½ MHz). This emitter circuit has to be tuned below the overtone frequency of 43⅓ MHz. Too low a LC ratio, at perhaps 25 or 30 MHz, may not give enough regeneration at the 130 MHz collector frequency with some transistors to give good output power at 130 MHz. The TIXM05 crystal oscillator functions very well with a 5-25 pF adjustable ceramic capacitor and a 3 μH rfc. The TIM10 is a little marginal with these values and perhaps a 4 μH rfc and smaller capacitor might be better. The proper values are those which provide a very weak 43⅓ MHz oscillation at the overtone crystal frequency and doubling or tripling power to the desired output frequency in the collector to emitter system. Low rf power oscillation at 43⅓ MHz should mean low rf crystal current with attendant high frequency stability. However, the transistor has to oscillate at 43⅓ MHz and efficiently triple to 130 MHz. Regeneration at 130 MHz helps increase the 130 MHz power output without running much rf at 43⅓. These oscillators, where one does the work of two, can be made more stable in frequency but do require some experimenting to get them to work with each change in transistor type.

The 3 microhenry coil can be wound from coil table or calculator data, or it can be a commercially made small encapsuled rf choke. If one doesn't work, don't be afraid to try another one as the tolerance on some rf chokes is awfully wide. Actually, a ferrite-cored rf choke of 3 or 4 microohms will have a higher Q than "air wound" varieties and produce oscillation more easily. The unloaded Q of this coil should be at least 15, with higher values being desirable. The transistor should be a type with good vhf gain and a cut-off frequency of at least six times the overtone crystal frequency, and a few times the harmonic frequency desired. Like most harmonic generators, the second harmonic is upwards of twice the value as for the third harmonic. The fourth harmonic is usually too low in amplitude to be used in vhf converters. . . . W6AJF

Two-Meter Heterodyne Mixer

While SSB is becoming widely accepted on the high frequency bands, AM still reigns above 30 mc. Drift is the foe of VHF SSB since both transmitters and receivers have to stay within 100 cycles to be of any use. Lack of stability is one of the greatest factors keeping HF SSB men from enjoying SSB on VHF in spite of its many advantages.

But drift can be conquered. Conventional techniques for VHF call for multiplying a fundamental many times to the required band. This obviously multiplies drift many times, too, so that most HF vfo's are unsatisfactory on two and above. But the method of changing SSB frequencies is heterodyning. This additive process keeps the drift down to reasonable levels. High quality overtone crystals for this process are now available at low prices. In fact, you can often borrow a little oscillator injection from your receiving converter.

Frequency generators and mixers

When used as frequency converters, modulators are more commonly called mixers. A broad classification of mixers is into balanced and unbalanced types. These can be further

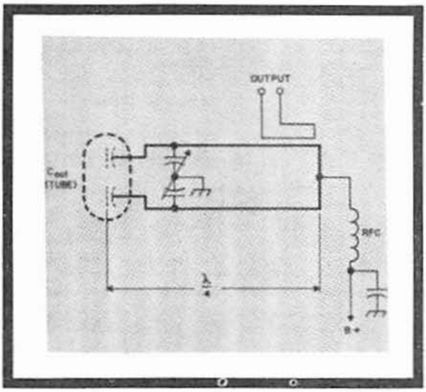
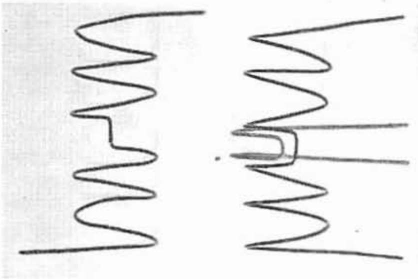


Fig. 1. Typical quarter wave tuned circuit. The quarter wave line can be rolled up as in the balanced tanks in this transverter.



Standard center tapped coil on the left. The folded tuned (quarter wave) line is on the right. Note how the pitch reverses at the center and how coupling is achieved. L7, L12 and L13 are made in this manner.

divided into efficiency and power (brute force) mixers. Balanced mixers provide suppression of the carrier and excellent distortion figures. However, they are a little more complicated than unbalanced ones.

Brute force mixers are rarely used in practical heterodyning equipment because of the high power requirements. Efficiency mixers are much more common. Various schemes of modulation have been tried in mixing–grid, screen, cathode, grounded screen. Each has its merits and demerits:

grid: low drive and modulation requirements but low output.

screen: high output but high screen current.

cathode: good output but low plate efficiency.

Grounded screen: low screen current and good quality but low efficiency.

One form of mixer which has not seen much use in the HF and VHF bands is the suppressor modulated pentode. While it is true that screen current can run higher than normal because of the negative bias on the suppressor grid, this type of mixer possesses excellent quality, stability and overall efficiency. Drive required is very small. Because the suppressor

has a negative bias on it the modulator need supply only voltage in most cases. Plate efficiency can run as high as that of the same stage operating in class B. Quality is excellent through high percentages of modulation.

In recent experimenting with a 50 mc mixer, We came across a very attractive circuit using the 6BU8. This tube is designed for combined sync separator-clipper and AGC in television receivers. Nevertheless, it does an excellent job as a balanced mixer for ham applications. The basing leaves a lot to be desired, but the layout I used provided excellent results with no cross socket shielding. The 7360 could possibly be used in this circuit since its maximum operating frequency is above 100 mc. The major advantage of the 6BU8 over the 7360 is its relative tolerance to magnetic fields. The 6BU8 can't be mounted on the filter choke in your power supply, but it does not need the extensive shielding required by the 7360. Incidentally, the 6HS8 is very similar to the 6BU8.

Circuit details

Briefly now, an explanation of the operation of this unit. V1, the 6AB4 (or half a 12AT7) is a standard third overtone oscillator at 41 mc. The 51 k grid resistor was chosen for good output with best stability and a minimum of crystal current. V2A, the triode section of the 6AU8A, triples the 41 mc output of the oscillator to 123 mc. V2B, the pentode section, operates as a class C amplifier and supplies ample drive for the mixer. This amplifier also provides isolation from the oscillator string and furnishes an extra tuned circuit for cleaner drive.

Grid number 1 of V3, the 6BU8 mixer, is fed with the 123 mc local oscillator signal. The 21 mc from your SSB or other transmitter is fed push-pull through the L4, L5, C4 network into the suppressor grids. The 144 mc sum signal is selected by the push-pull plate tank L7, C5 and coupled to the grid of the class A 6AK5 driver, V4, through the two L8's (oops), and C6. Again, an amplifier is used to insure a clean signal and sufficient drive to the following stage. The output of the driver is then applied in push-pull to the grids of the 6360 final. Output is about 10 watts PEP or 4 watts of carrier depending on what you feed to the suppressors of the mixer.

With 225 volts on the plates, the output of the final is sufficient to drive a pair of 4CX300A's to full input. The quality of the

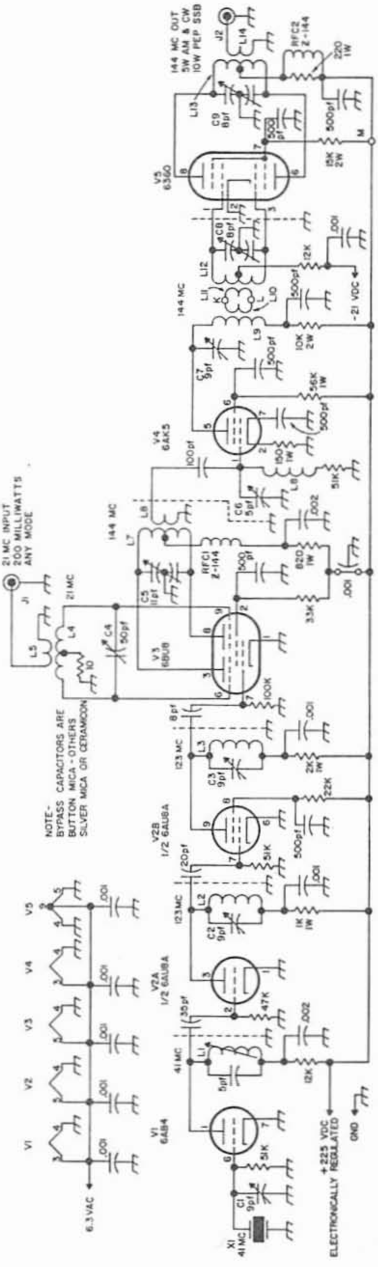


Fig. 2. Schematic of the Two Meter Heterodyne Exciter. 200 mw at 21 mc gives you 10 watts PEP output on 144 mc. For layout and shielding details, refer to the photographs.

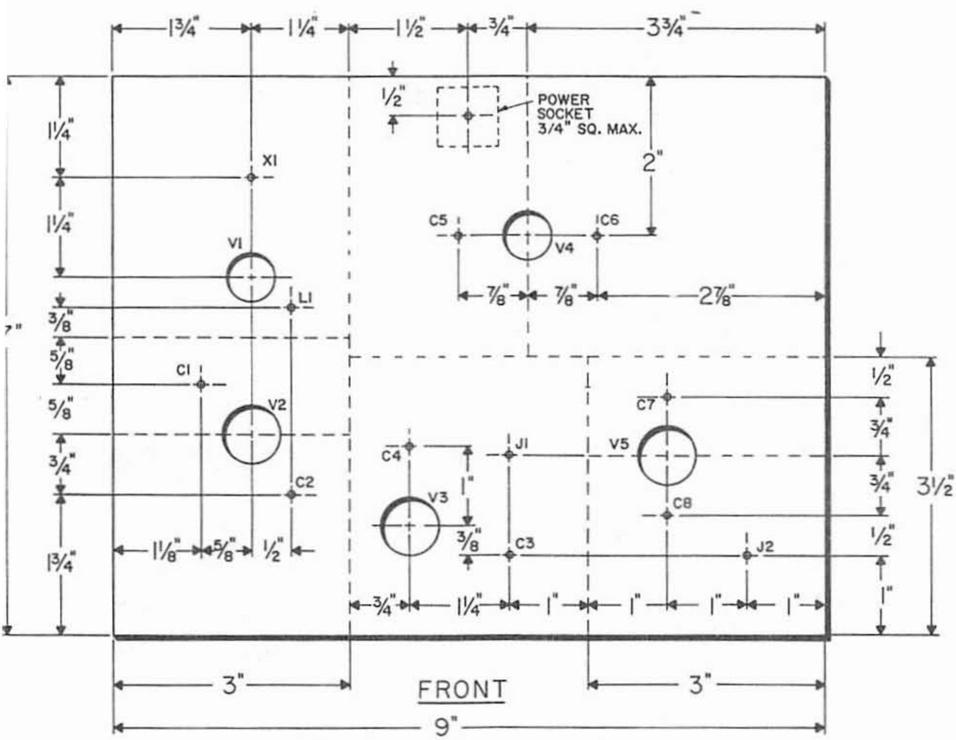
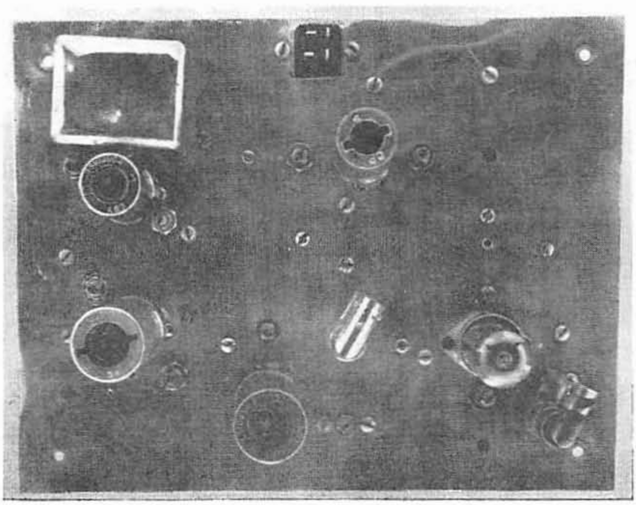
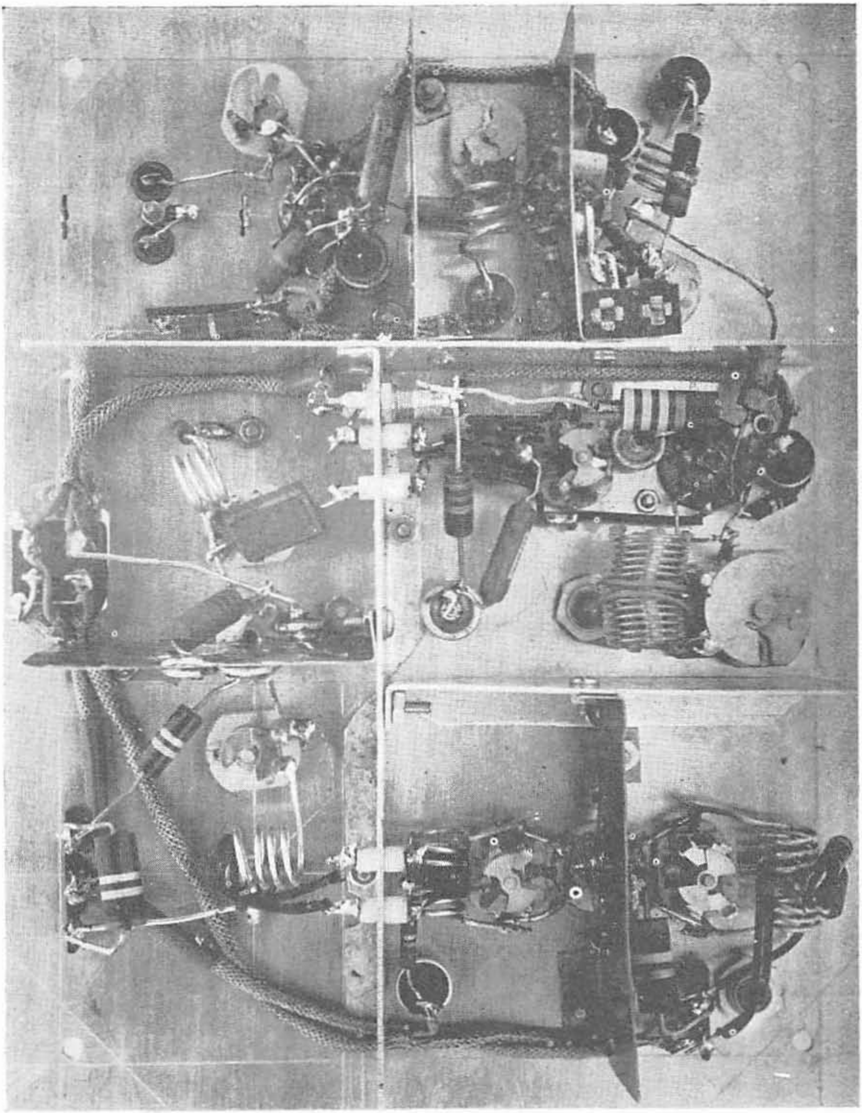


Fig. 3. Half size drilling template for the 144 mc transverter. Small circles only locate mounting centers. The dashed lines indicated shielding. The unit was built on a 7 x 9 inch aluminum plate which was bolted to a 7 x 9 x 2 chassis.



Top view of the exciter. Counter-clockwise starting at the top left are crystal, V1, V2, V3, J1, V5, J2, V4 and the power plug.



Bottom view of the exciter. Wiring is nor too near but it is in keeping with good VHF practice and gives a good idea of the parts placement. Top left hand section is the 6AB4 41 mc oscillator, middle top is the 123 mc output of the 6AU8A tripler. Top right is the output from the 123 mc amplifier, which feeds into the 6BU8 mixer below. Output of this mixer goes to the 144 mc input of the 6AK5 amplifier on the middle left. The plate circuit of this 6AK5 is in the lower left. It is link coupled to the grid of the 6360 final in the bottom center. The output of the 6360 is in the lower right to a BNC.

Table 1 Voltage Chart

Tube Pin	*V1 6AB4*	*V2 6AU8A*	*V3 6BU8*	*V4 6AK5*	*V5 6360*
1	+115	0	0	0	−21
2	0	−0.15	+165	+1.25	0
3	6.3 vac	+220	+225	6.3 vac	−21
4	0	0	0	0	0
5	0	6.3 vac	6.3 vac	+160	0
6	−3	0	0	+100	+225
7	0	−1.15	−6	+1.25	+195
8	—	+135	+225	—	+225
9	—	+190	0	—	6.3 vac

output signal is as free of distortion as the HT-32 that drives it. Incidentally, quality will be degraded if you feed over ½ watt into the mixer. You'll need to retune the circuits if you travel over 400 kc.

Power supply

I am using an electronically regulated supply for B+. This is recommended as it assures a constant voltage on the oscillator for stability and constant voltage on the stages in linear operation.

Adjustment

You'll need a 20,000 ohms per volt multimeter and relative power meter or swr bridge for initial tune up. A grid dip meter is a great help in pruning coils and setting tuned circuits to frequency.

With B+ only on the oscillator (check this voltage) and the slug as deep into the oscillator coil L1 as it will go, slowly screw the slug out until the 6AB4 starts to oscillate, as evidenced by bias developed at pin 2 of V2. Set the slug in this position. Turn the plate voltage off and then reapply it to be sure that the oscillator takes off again. If it does not start up again try a different setting of the slug. In general, the optimum setting is at a frequency slightly higher than the setting which produces maximum output. Turn the power off and connect power to the tripler and the injection amplifier. Reading bias voltage developed across the grid resistor of the 6BU8, tune C2 and C3 for maximum voltage. In order to get a reading to tune C2, the meter may have to read the voltage on pin 7 of V3. At this point check the voltages at all pins on V1 and V2 against the voltage chart.

Again turn the power off and connect the B+ to all other stages and the bias to the final. Before turning the B+ on, be sure that there is −21 volts of bias on both grids of the 6360 (pins 1 & 3 of V5). Apply power and check the rest of the tube pins for voltage against the chart. If less than one volt or more than three volts appear on pins 2 & 7 of the 6AK5 (these voltages must be positive) turn off the power and determine the cause. Check for plate voltage first. If it is present, check to see if the cathode resistor or bypass capacitor is defective; if so, replace the faulty component and try again.

When bias is present on the cathode of the 6AK5, apply about 100 milliwatts of 21 mc drive to the suppressor grids of the mixer and, using the power indicator, tune C4 through C9 for maximum 144 mc output. Remove the 21 mc signal and be sure that the output goes to zero. All 144 mc tuned circuits should hit 144 at about half capacitance if they have been properly constructed. With the exception of L8A, C6 all 144 mc circuits should not tune lower than 133 mc. If output remains after 21 mc drive has been removed, get out the GDO and find out why. If good shielding practice has been observed there should be no trouble with spurious oscillation.

When all appears to be in proper order, reapply the 21 mc drive at about 100 mw. If grid voltage on the 6BU8 is near that listed in **Table 1**. the local oscillator chain may be retuned for maximum output at this time using the power meter for reference, this step may not be necessary. Slowly increase the 21 mc signal until the output peaks. Note the setting of the drive control or loading at this point and, when on the air, operate with a little less 21 mc power than this. If the 21 mc drive is at a higher level than this the unit will overmodulate, distort, and the output will drop. A good idea is to construct an attenuator to drop the full output of the generator to that level required by the heterodyne unit.

Coil Table

	Turns	*Diameter*	*Wire*	*Form*	*Length*
L1	8	⅜	22 en.	iron slug	close wound
L2	3	⅜	16 tin.	air wound	⅜
L3	4	⅜	16 tin.	air wound	½
L4	14 CT	½	20 tin.	air wound	⅞
L5	2	Insulated hookup wire at center of L4.			
L6	There is no L6			Folded line. See photo.	½
L7	4½	½	16 tin.		
L8	1	Insulated link at center of L7.			
L8A	3	⅜	16 tin.	air wound	⅜
L9	4	⅜	16 tin.	air wound	½
L10	1	Insulated link at cold end of L9.			
L11	Same as L8.				
L12	5	⅜	16 tin.		Same as L7.
L13	7	Same as L12.			
L14	Same as L11.				

. . . WA2JAM

RF Insertion Amplifier for 2 Meters

Things get tough when you get up into the VHF-UHF range. You often get to 144 MHz and find everything running nicely, except that you haven't enough power to drive that final.

An insertion amplifier can be a good answer. It works just like the name says. You insert it between the exciter and the final, for example, to boost the drive to the final. You can also use it in the design of a complete rig, of course. This one will accept an rf input from ¼ watt to a watt or so, and put out from several watts up to 20 or more, depending on the drive and dc input.

The 8156 as an insertion amplifier

The 8156 is the baby brother of the 7984. Both are G. E. tubes rated for use up to 175 MHz, the 7984 costs $5 and puts out 50 watts, the 8156 costs $4 and puts out only 20. The 8156 is hard to beat at this price.

If you are interested in an amplifier with lots of gain which will put out 20 watts on 2 meters and has a lively plate dip, this is it. See **Fig. 1.** Another attraction is the socket. It uses the same connections as the 7984. It is also very sensitive to small signals (transmitted) and can be made part of an exciter if you wish. It should, perhaps, be attached to the final, though, as it has a 12-volt filament.

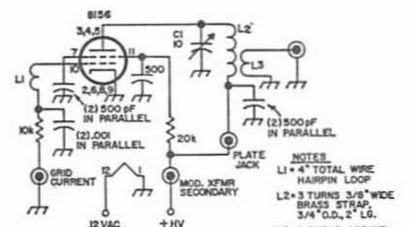


Fig. 1. If you are interested in an amplifier with lots of gain which will put out 20 watts on 2 meters, this is it.

The plate dip, when using only ¼ watt drive, is from 100 mA down to 35 mA. You can get a good 6 watts out from the ¼ watt drive; which is a gain of some 24 times in power. If you push it, the gain and efficiency will both go up. At 20 watts dc input, the output is almost 10 watts. This is not maximum efficiency, but we are only concerned with an insertion amplifier for step-up purposes from a low-power exciter.

For most applications in driving a final amplifier in the 50 to 100 watt range, the rf power output from the 8156 will be plenty. You can go from a watt or so up to 20, which is very useful. You can also modulate it for use as a low power transmitter, using it for 5 or 10 watts output until you can get that 25-watt modulation transformer and the 50-watt final.

You can put a 7984 directly into the socket of the 8156, but you will have to shorten the grid loop a little. That's about the only change needed. The plate has a little higher capacitance also, but should stay in the 10 pF range of C1.

One note: *do not use one of those black molded-mud sockets on 2 meters.* I keep talking about these things, and yet time and again, I get stuck with one. Low-loss 12-pin sockets just aren't available in the stores. So, I put in a "black" socket, and what trouble *that* gave me; I spent more than 2 days trying to get a decent plate dip. You understand that when I talk about a plate dip, I am using this as a reference for a high Q plate circuit. If you leave the drive and tube voltages alone, the dip will be a direct indication of the Q of the circuit. There is a lot more to this, of course, but this will give you over 95% of the desired test results.

Almost desperate, I finally had the luck to hear a little crackling noise and see a thin line of blue smoke rising up from the vicinity of the plate side of the socket. Pushing the plate and screen voltage up, and leaving the plate dipped so that a maximum of rf voltage developed between pins 3, 4, and 5 (all plate pins), and the grounded socket rim, an arc soon developed and that was that. You

should see that socket. It looks as if you had held a match under it.

Taking one of the more low-loss 12-pin sockets out of a perfectly good piece of low frequency equipment in the shack, I replaced the black one. Without any other changes, the plate dip went from 70 mA (out of 200) down to 50 mA. Some difference!

Now things began to move. I could get a 50% plate dip with only 150 volts on the plate. And, about 50% efficiency with about 10 watts out. Note that is with only ¼ watt of drive. No self oscillation occurred at any time using the low-impedance type L1 on the grid.

I was now able to find out exactly how much drive the big final needed for absolute maximum rf out, by controlling the plate voltage of the 8156, and also could run my crystal vfo exciter at very low, stable power.

The 5763 as an insertion amplifier for 2 meters

If you have some 5763 tubes on hand, they will do the job for you; though not as well as the 8156. The 5763 is indicated for maximum ratings to 50 MHz. But, let's see what it can do in spite of that. A number of days on the bench were the result of

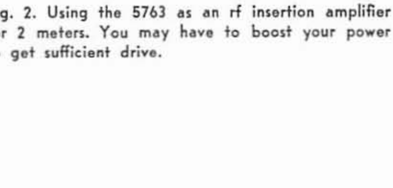


Fig. 2. Using the 5763 as an rf insertion amplifier for 2 meters. You may have to boost your power to get sufficient drive.

that decision. I could get a power gain of between 10 and 15 under certain conditions, but it seemed reluctant to "go" on 2 meters. Working carefully with the grid and plate circuits, the best plate dip I could get on 2 meters with about ½ watt drive, was from 40 mA down to 34 mA, and about 1.5 watts out.

The poor plate dip on resonance seems the best indication of its sluggishness on 2 meters. If you have some 5763 tubes available and don't feel like getting an 8156 just yet, you can use the 5763 and perhaps boost your power enough for the drive you need. **Fig. 2** shows the circuit; which is not complicated.

Pay attention to the grid circuit, though. We spent lots of time on this one, and another like it for the 8156. I was able to set up a 2-meter tuned-grid circuit in spite of the large input capacitance and lower frequency ratings, but when using a tunable-grid circuit, more grid current was lost on applying dc screen and plate power than with a fixed tuned 11, and, even worse, self-oscillation showed up. So, I went back to the grid loop. The entire "grid coil" is a single piece of wire 3 inches long and bent into a U.

This does not allow for a cable link from the exciter, but we have not been able to get a cable link to equal the efficiency of the close-coupled low-impedance loop feeding directly into the grid.

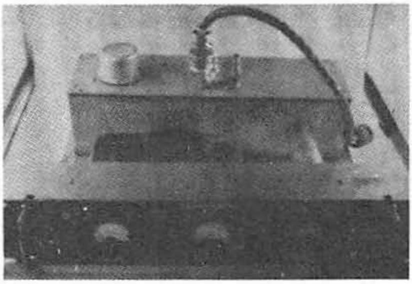
This unit, with 250 volts on the plate and 40 mA of current, will put out a watt and a half, if everything is tuned up properly. It is a useful piece of equipment, but today the 5763 is a little out of date for VHF.

The 8156 unit is far superior.

. . . K1CLL

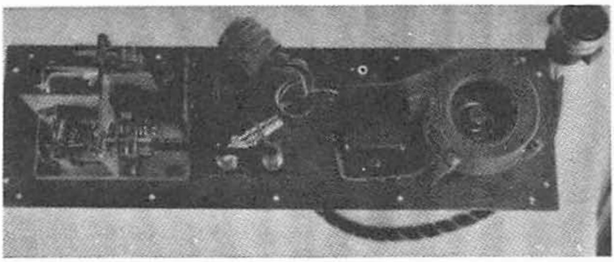
APA-2 Preamp for 2 Meters

The APA-2 preamp can be found on MARS and surplus lists and seems to be missed by a lot of VHF hams. This unit can be one of the most important components for VHF DX work. There seems to be little or no information as to its original use but has high gain and low noise for 2 meter through 432 mc. The units found locally on surplus were all manufactured by the Applied Science Corp. and ranged from 200 to 300 mc in their original form. The APA-2 consists of a power supply unit and the preamp chassis. The power supply unit is completely metered for heater voltage, plate current and plate voltage. Each circuit is adjusted on front panel for a varying voltage and current applications. Besides the ON/OFF switch there is a switch for leaving the blower on the preamp chassis running while all voltages are removed from preamp during stand by. Preamp chassis units contain a 416B and 6BQ7 follower. No modifications or changes are required in the power supply unit. The power supply is rack mounted for 19"x3½" and makes a neat panel arrangement with the pre amp unit. The connecting cable, if you were lucky to get it, can be lengthened or shortened to meet your needs in mounting. As the photo shows the preamp contains the following items: 416B with tube socket, 6BQ7, and coils in an RF box. It is cooled by a 110VAC blower and the antenna input and preamp output connection can be seen. The units here for local hams have been charged to 2 meters in the following way. The antenna input coil in the cathode of the 416B was removed and re-



Front view of the APA-2 power supply with the preamp in the rear.

placed with 4 turns #18 on ⅜ ID form. The coil is tapped up 2½ turns from ground and connected to an input terminal. Next the plate coil of 416B was removed. This was replaced by a ½" slug turned form. The mounting hole for the coil form had to be enlarged to hold the ½" coil form. On this is wound 5 turns of #18. One end of coil goes to the 416B plate and the other end goes to B+ for the 416B. The original circuit here is coupled to 6BQ7A by a 56 pf capacitor. I have found that if only the 416B is to be used, a two turn loop at plate end of the 416B plate coil form would couple to the output. If the 6BQ7 follower is to be used the signal is coupled by the 56 to the 6BQ7A. The plate coil of 6BQ7 is broad enough and no changes here proved necessary. The output coil at the pre-



Rear of the APA-2 preamp. The blower, connectors, 6BQ7 and 416B can all be seen with the cover off.

amp output connection is 4 turns of #18 tapped 2½ turns up from ground. The RFC chokes can be changed from Z235 to Z144. The plate coil of 416B and 6BQ7A are tuned to a band pass of 135 mc to 150 mc with a peak at 145 mc. The basic schematic is the same as shown in various VHF handbooks and no changes in values are needed.

. . . W5LTR

Shoulder Strap Portable

There are times when several developments that seem to grow up more or less independently can be assembled together in what the French call a "happy marriage." This is the case with the instant-heating 5816 tube; the really non-spillable, non-gassing, small and low-cost storage battery; good portable beams; practically wattless low-noise transistor receivers, and last but far from least, the increasing occupancy of the VHF bands, namely, 6 and 2, where reasonably sized portable antennas are practical.

When put together, these ingredients make for a new-type of amateur station. This is the shoulder-strap portable rig, a real emergency type with which you can get out and away from the car, walk (or climb) up that mountain or five tower for an additional 50 to 500 feet of elevation. (This also gets you away from super-regenerating Six'ers!) For *real* camping it is excellent, and it is always a nice thought to have a good, selective, complete emergency rig on hand. (One that doesn't need an AC plug!)

Starting with the 5816 tube, we find here a little marvel: the miniature equivalent of a 6L6GT. It uses 6 volts, but is instant-heating. This means what it says. You do not have to leave the transmitting filaments on while receiving. This type of operation is no news to mobile rig designers, but there seems to be a great number of amateurs that are not familiar with it. Don't forget that while receiving, zero transmitter power is used, and you have to carry that power.

There is only one precaution with the 5816. Do not run the screen at more than 75 volts. This is a red-hot beam power tube and will perform miracles when used right. It also uses only 225 ma of filament current.

Now for the circuit: Fig. 1 shows the 3 tube 6 meter unit. Nothing has been left out. It has 100% modulation, crystal control, and runs up to 7½ watts input, but to play it safe, keep it at 5.

Much has been written about VHF crystal oscillators and a lot of work has been done on them.

Just be sure and use *non*-regenerative feedback coupling in the grid-crystal circuit from the plate. This prevents all oscillation until you reach the crystal resonant frequency. At this point (crystals with ac on them always develop plus voltage on one side, minus on the other, at any given moment) the crystal will reverse the phase and apply good regenerative voltage to the grid. A lot of handbooks tell you to use regenerative coupling to help VHF crystals. Well, here is one circuit that works better the other way!

The plate circuit uses the well-known B & W air-wound coils. Every amateur should have a selection of these on hand for any and every use. They do work much better than slug-tuned coils if you have the room, cutting down TV and FM harmonics and pulling in 6 meters only! Copper-clad bakelite makes a good easy-to-build base, and provides an excellent ground. Don't forget the VHF and up rule: a "ground" is a place where most all of the rf has been brought to a halt. You can bring bypasses, coil returns, tube filaments (in this rig) etc., to this point and they will stay quiet. The trick with the copper-clad bakelite is mechanical strength, light weight, and it solders with a touch-of-the-iron.

A good trick in the B+ bypassing for rf coils at VHF frequencies is to use more than one capacitor. Just be sure of the voltage rating. When you do this, you can ground the shaft of the tuning capacitor rotor. There is some choice in CV1. If you stay within half of a megacycle on the band this can be a trimmer. If you want to cover 50 to 54, bring the shaft of a Hammarlund midget out to the front panel with a piece of insulated shaft.

Use light coupling to the final grid. This doesn't load the oscillator too much, and remember that the 5816 is red hot and doesn't need much drive. The final grid is furnished with bias as a precaution.

The rf final has the capacitor CV2 directly across the coil. It is better to take a little time for this for this is where the *power* is, and a class C amplifier needs every drop of "Q" it can get. Mount CV2 on a separate piece of bakelite, using an *insulated* shaft on it.

A swinging link completes the output circuit, unless you want to couple in a power output monitoring diode at this point. (We did.) Couple it to the antenna jack, not the

coil. With a little more work you can make the link adjustable from the outside. (We didn't.)

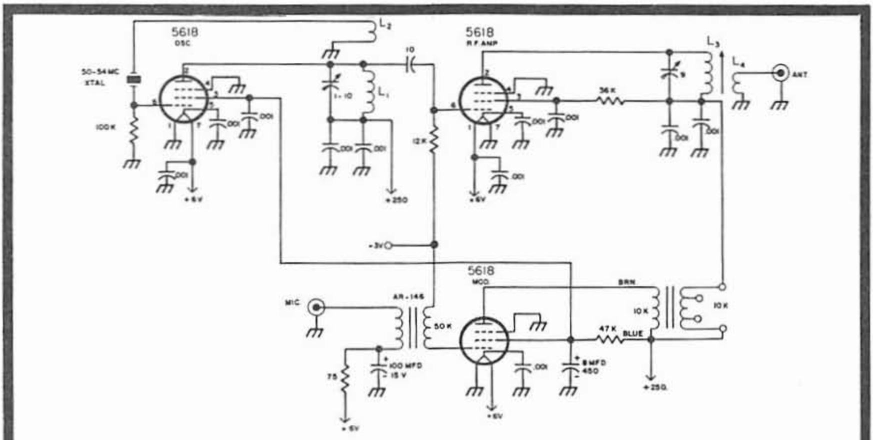
The modulator uses a carbon mike. (You cannot use a crystal mike without considerably more circuitry and battery drain.) If you use Western Electric F1 surplus buttons, the quality will be definitely good. A high gain transformer, Argonne (Lafayette) no. AR-146, primary 30 ohms, secondary 50 k gives plenty of audio drive on the grid. Incidentally, we have used a transformer with a 300 k secondary with even better modulation. Be sure to use the voltage dropping resistor and bypass shown for the mike voltage. 1.5 volts is ok. The modulation transformer is a standard low-cost job just suited to this purpose and rated at 5 watts. Connect it as indicated on the diagram.

Any dc to dc converter may be used, but do not go over 300 volts. 225 or 250 is plenty. A power saver switch on the supply, cutting the B+ to about half, is a good idea for local contacts. Don't forget, if you use this rig on a mountain top with a good portable beam, you will soon be surprised at the stations you consider "local"!

A word of caution here. Dc to dc power transistor circuits generate "spikes" on every possible occasion. Barrels of "dead soldiers" in many labs across the country have been the result of those reverse voltage spikes. The trick lies mainly in the transformers and, of course, push-pull. Barker and Williamson furnished this transformer. Triad also manufactures this type of unit. Maybe you should buy a ready-made kit. Anyway, this one has worked well now for over a year with no trouble. Incidentally, due to the low-drain receivers used, this supply is only turned on with the transmitter filaments.

And now for the portable battery that has the energy stored in it to get you on the air on that hill top. "Miracle" batteries have been featured in many articles since the war. Some of them really are miracles. Batteries small enough to be swallowed in a pill; batteries you can hold in your hand and that will furnish a kw of power (for one minute!); a D size flashlight cell with 14 ampere-hours of energy stored in it (that one always seemed to me to a real miracle!); etc. However, when first cost, weight, size, ease of charge, explosive power, "seeing what goes on" inside and compatibility of voltage with available tubes, ditto with car batteries; are all carefully considered, I always seem to end up with the old reliable lead-acid battery, but in a new form. There is a lead-acid storage battery that really does the job for portable amateur work. It has transparent walls so you can see the water level and condition. It has a really nonspillable baffle, vent, and plug arrangements so that only dry gas comes out when charging or discharging.

Also, by starting with one small 6 volt unit and then adding more of them, you can get double ampere-hours (time on the air), or wattage (power on the air), or voltage (12 volt systems, or 24 volts for much more power), etc. However, here again there is a level above which it is better to use a straight ac gasoline driven generator. This of course, is beyond the definition of a "shoulder-strap portable." All this seems to show that there is going to be a power level limit for "portable" stations: that is, just how much power



Shoulder-strap portable.

you can walk (or stagger) up a mountain with and then stay on the air for at least an hour or so.

Here are some suggested transmit-receive circuits for the 5 watter portable. A three-pole, double-throw slide switch has been used successfully for a year. Remember, this is still a low-cost station. Of the three sections, sw1 turns on the receiver filaments; sw2 switches the antenna; and sw3 turns on the 6 volts to the transmitter and transistorized dc to dc converter. A rotary 4 pole switch could also be used, but is more expensive.

Use coax cable right close up to the slide switch. This is ok at least up to 50 mc, especially if you use the copper-clad ground mentioned before.

For assembly of the complete rig, an arrangement consisting of ⅜″ plywood shelves, with ¼″ sides, and a dowel handle across the top will prove satisfactory.

For the antenna, two 4½ foot aluminum pieces with two banana plugs each (4 total) plug into banana jacks on a piece of bakelite bolted to the top of a piece of 5 ft. TV aluminum masting makes a fb dipole that packs into a 5 ft. long thin package.

All these items together used on a mountain-top put you quite a ways away from the usual idea of a "walkie-talkie" rig, as you will find out.

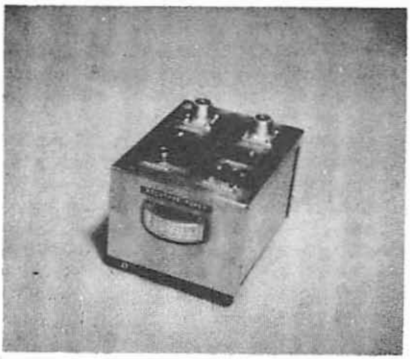
. . . K1CLL

Handy VHF Monitor

The need for a good quality AM monitor for VHF becomes apparent when you delve into high power 2 meter linear adjustments. Using a TX-62 to drive two PL-177WA's in Class B AM linear requires a device which can be installed in the output line of the linear so that bias and screen voltages could be properly set. Minimum distortion of the modulated driver is the goal. Careful experimentation yielded an improved circuit which is presented here. Incidently, most oscilloscopes are ineffective for use on VHF, unless you go directly to the vertical plates: and who wants to botch-up a commercial unit?

Equipment Description & Schematic

The completed VHF monitor is enclosed in a 3 x 4 x 5 inch Bud Minibox. At the rear are the two SO-239 IN/OUT chassis connectors. Either one can be used for input or output to coaxial line. Next, to the left, is an audio jack of the kind that mates with PL-55 type mike plug; but in this case, is used for listening with HI-Z headphones. To the right is an SPDT slide switch: giving you a choice of "Power," or "Monitor" switch positions. With a flat line, relative power measurements can be made; and if you follow the instructions given later



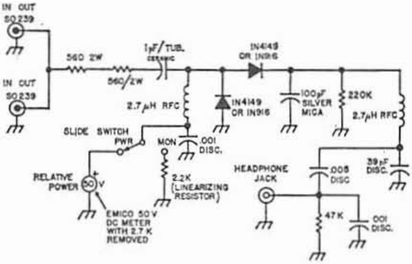


Fig. 1. Schematic for the Monitor.

on: an "engineered-guess" can be made as to the actual power present.

The EMICO™ meter is mounted by a rectangular retaining speednut in the front wall. To the upper right is the 2.7 μH RFC and the 1N4149 diodes are wired in near this. Observe that the 560 ohm/2 w. resistors are wired to the SO-231 jumper with both resistors in series—first—and then over to the rf coupling capacitor (1pF). They must be connected this way, otherwise enough energy could be coupled in to destroy the diodes.

Fig. 1 is the schematic. The half-wave doubler/detector is straight-forward. It is interesting to note that the coupling value of 1pF works best on the "monitor" position of the unit (listening) for 2 meters, with 100 pF as the output to the audio filter. The same ratio of 1 to 100 holds for the "linearizing resistor" as compared to the output dc load of 220k. The 2.7 μH RFC are chosen to have an impedance maximum just above 2 meters (149MHz) & 39pF discoidal capacitors are series-resonant near the two meter band with usual lead-length. The 0.001 bypass is a ceramic disk, chosen for a low value of reactance as compared to the internal meter resistance. The remaining components comprise the audio filtering and coupling.

Using The VHF Monitor

Any power level up to a kilowatt dc input, on two meters, will drive the voltmeter

to some position on the scale. 432 would be an upper nominal frequency limit with this unit; however, the "relative power" meter would have little meaning, but it would be useful for tuning-up. If you wish to modify the design for 432, use Z-460 chokes and 13 pF discoidal ceramics. The other capacitors should be left as is. Of course, even with a flat-line you can expect considerably higher meter readings on this band.

On 2 meters, an Ameco TX-62 will give a reading on the meter of about 7.5 volts; for an AB_1 *rf* linear we registerd 15 volts. For the big half-kilowatt Class B linear, we observed 30 volts! A nominal 15 volt reading is equivalent to 75 watts into the monitor in the "power" position; but remember, you must have a flat-line or this doesn't mean anything. And these indications were made from notes in our set-up using a Bird™ Model 34 Directional Wattmeter, in series with the VHF monitor.

Just above we said that "any transmitter" could be used. Don't expect a TWO'er to do more than jar the meter; You will get enough audio through the detector to listen to the signal, though. The main use for the 'Darn-Handy' is to set up 75 watt transmitters & big amplifiers we use at W4KAE. When adjusting a stage, plug in the headphones, after peaking the output: and listen for maximum *background audio pickup*. Bias and screen voltage controls are to be varied for this purpose. Make sure the slide switch is in proper position. Background pickup is like an increase in gain; without changing the audio level! Preset audio before this step; and you will find bias adjustments related to detected audio. Once you hear the increase in gain, NOW advance the audio gain until the signal is raspy or tinny. Set the audio gain back about ¼ and you're linear. If you can't get enough power output . . . with linearity . . . try increasing the amplifier screen voltage, and repeat the process.

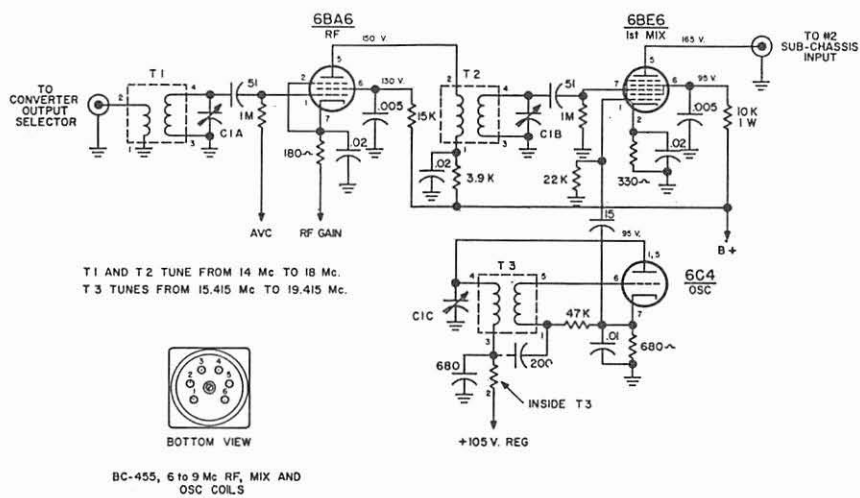
. . . W4KAE

Receiver for 6 & 2 Meters

The receiver described in this chapter consists of a tunable *if* covering a four megacycle range from 14 mc to 18 mc. Detectors are provided for AM, CW and SSB. Controls include audio and rf gain, noise limiter, SSB/CW-AM mode, avc, and selection of either a six or two meter converter or tunable *if* input. The approximate cost of the receiver including the two VHF converters and all new components will be less than $200. A minimum of tube types were used in order to keep tube inventory reasonable. Some of these new receivers use a different type tube for each stage of the set.

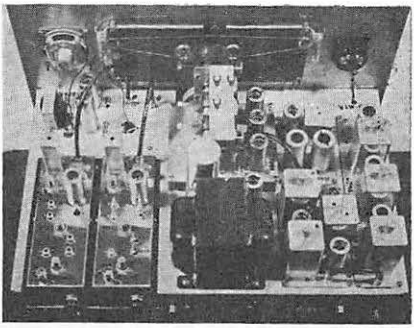
Circuit Description

The receiver circuitry begins with an AMECO six or two meter Nuvistor equipped converter whose output covers the 14 mc to 18 mc band. A selector switch controls the B+ to each converter and the appropriate rf output to the input of the receiver. The receiver consists of four sub-chassis. The first is a tunable front end covering 14 mc to 18 mc whose output is 1415 kc. The second sub-chassis amplifies the 1415 kc signal through one stage of *if* and converts it to 239 kc. The third sub-chassis consists of two stages of low frequency *if* amplification and an AM detector, avc detector, and the ANL stage. The fourth sub-chassis



#1 SUB-CHASSIS VHF RECEIVER

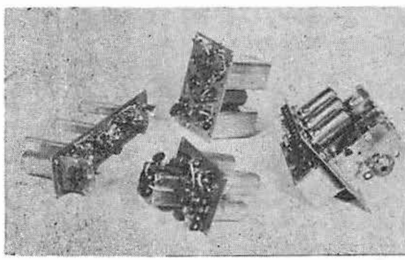
14 Mc-18 Mc TO 1415 Kc IF



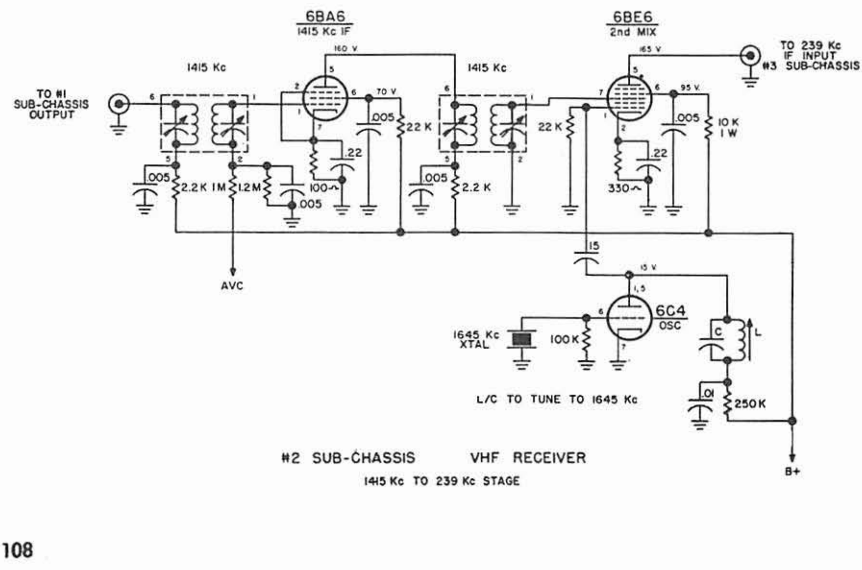
includes the SSB/CW detector, bfo and the tuning meter detector. The power supply and audio stages are located on the main chassis.

Construction

Two surplus ARC-5 command type receivers were acquired for junking purposes. These two units covered the range from 3 mc to 6 mc, and 6 mc to 9 mc. The tuning capacitor and the associated coils were removed from the 6 mc to 9 mc unit for use in the first sub-chassis. The gear mechanism was removed from the tuning capacitor. All the rotor plates but two were pulled from the rf and mixer sections of the tuning capacitor. Three rotor plates were left on the oscillator section. The rotor plates with all the slots that are used for tracking purposes are left on the rotor also. The oscillator, mixer and rf grid coils are modified by removing half the turns plus one. The original *rf* coil was connected to the antenna through a coupling capacitor. This coil is further modified by adding a new antenna winding over the cold end of the coil for antenna and ground connections. This coil is made from some of the wire removed during the above changes. It consists of about five turns. The tuning capacitor comes equipped with trimmer capacitors for the oscillator and mixer sections but none for the rf section. An Erie 7-45 mmf trimmer is soldered across the rf tuning section of the three gang capacitor. One end is soldered to the stator and the other end soldered to the frame of the tuning capacitor. This will provide trimming adjustments for all three stages of the front end to aid in tracking.



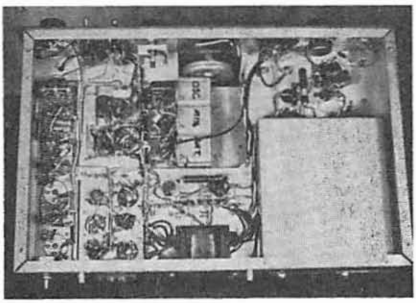
The modified coils are then replaced in their shield cans and each one breadboard con-



#2 SUB-CHASSIS VHF RECEIVER

1415 Kc TO 239 Kc STAGE

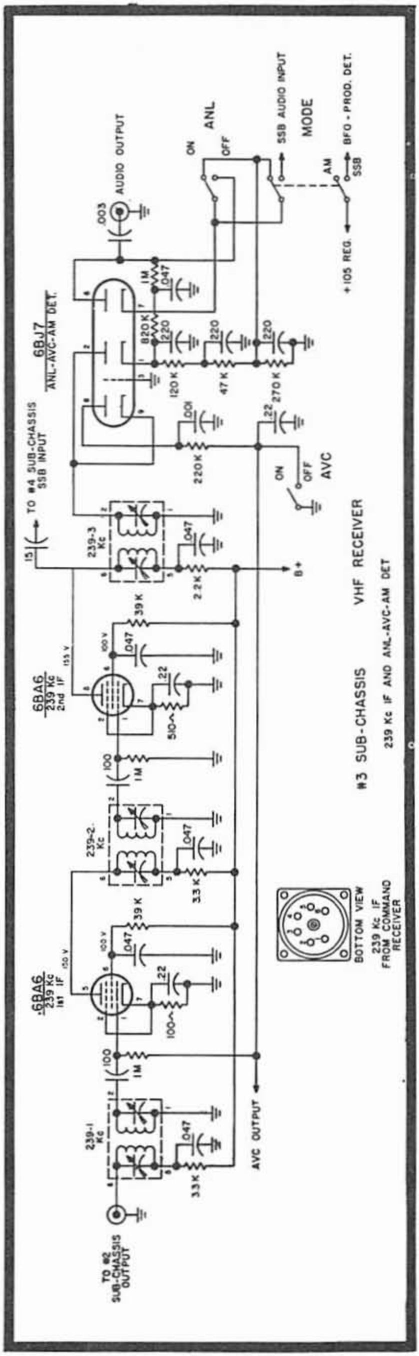
nected to the three gang capacitor to check for proper frequency coverage. The rf coil and mixer coil are checked for proper frequency coverage using a Grid Dipper. The oscillator circuit is tacked together and the frequency coverage checked with a Frequency Meter. The oscillator must cover from 15.415 mc to 19.415 mc, if a 1415 kc *if* is to be used. The rf and mixer coils must cover the 14 mc to 18 mc of course. The powered iron slugs found inside the coil forms are backed off until they are almost to the end of their travel. The trimmer capacitors on the three gang tuning capacitor are used to set the high frequency end of the dial, and the slugs are used to set the low frequency end of the dial. As would be expected in any coil tracking job there is interaction between adjustments.

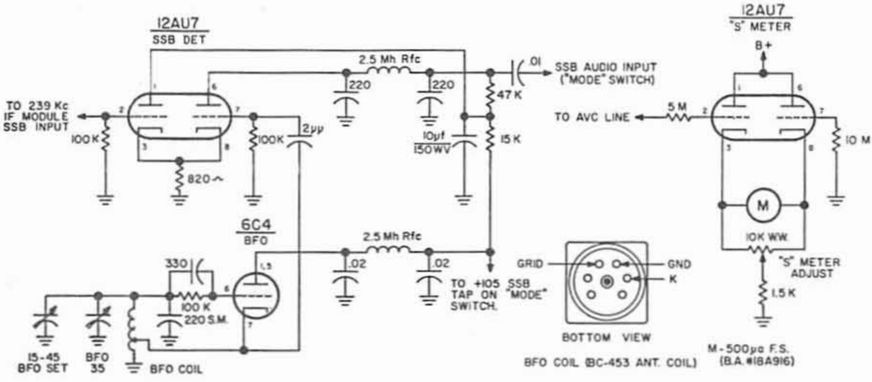


The 1645 kc oscillator coil on the second sub-chassis is constructed from a salvaged slug tuned coil form and mounted in one of the scrapped Command Receiver *if* cans. Its resonant frequency was determined by a Grid Dipper.

When third sub-chassis is finished wiring we hook it up to power supply and signal generator for *if* alignment. After this stage is aligned the second sub-chassis is temporarily connected to the third sub-chassis and given a checkout and preliminary 1415 kc alignment.

The bfo and product detector section gave me the most trouble. The original circuit used a 6BE6 product detector but I could not get it to function as I thought it should. The sub-chassis was removed from the main chassis and modified to use the old reliable 12AU7 double triode product detector circuit. The bfo coil is made from the rf coil removed from a BC-453 Command Receiver that can be salvaged in previous construction projects. The



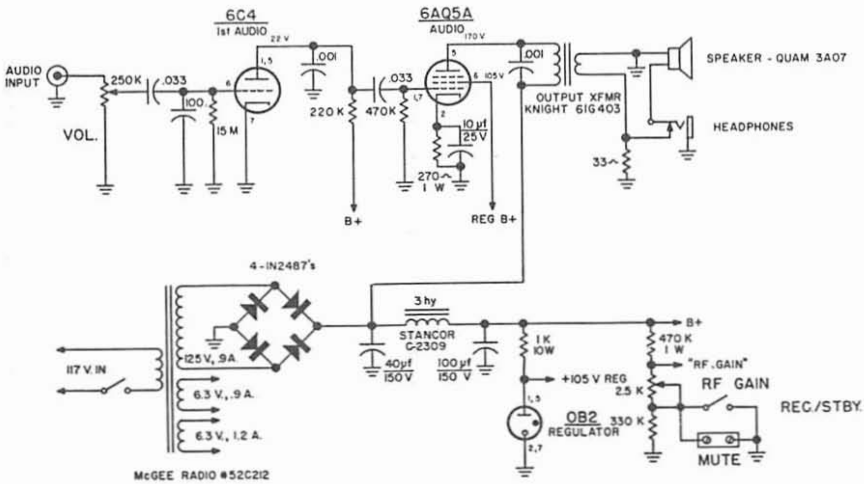


#4 SUB-CHASSIS VHF RECEIVER

PRODUCT DETECTOR-BFO-"S" METER

biggest problem using this coil was that I could not tell for sure at what frequency it was oscillating. Harmonics from the oscillator leaked into the 1415 kc *if* stage making it difficult to set the injection level on the product detector. A careful check of the frequency by a Frequency Meter indicated that it was too high. Additional padder capacitor brought it down to the proper frequency of 239 kc. This cleared up the last of the troubles with the receiver.

The cabinet is a LMB model W1D using a 11" x 17" x 3" chassis. The chrome trim on the front panel came from the dash of a junked car. The dial is one of those fine Ed-



#5 MAIN FRAME VHF RECEIVER

AUDIO-POWER SUPPLY

dystone units made in England. I added internal lighting by installing a pilot light at each end of the dial assembly. The pointer on the dial and the tuning meter are painted a bright red. The cabinet is a light grey, the front panel is dull black and dark grey. The dial is calibrated from 14 mc to 18 mc using the frequency meter. The remainder of the dial scales are geared to this calibration. Typical 432 mc and 1296 mc converters suitable for use with this receiver may be found in the 1963 *Radio Amateur's Handbook.*

. . . WØRQF

Tubeless VFO for 6 or 2 Meters

Most of our rigs on six (or two) are capable of using a tubeless VFO. Many think that a crystal puts out power. A quartz, frequency-controlling crystal represents a capacitance and inductance having extremely high "Q" so as to be an excellent stabilized tuned circuit. It is in effect a large frequency controlling flywheel. While temperature has a minor change factor, and the tube (or transistor) has some minor loading, the high "Q" holds the frequency very close to the crystal mechanical radio frequency resonant vibration design. But power does not come from the crystal. The tube or transistor give the amplification power.

Thus if we simulate a crystal by designing an inductance and capacitance to resonate at our desired frequency, we can make a tubeless VFO using the present crystal oscillator tube. But this VFO must be designed ruggedly, and made to be re-settable to our needed calibration.

On the Gonset and Clegg transceivers and for six and two, we do not require the stability that is needed for sideband. And thus we can make use of simplified designs that make the construction much easier.

Looking at Fig. 1, there is a tuned circuit L1 with a variable capacitor controlled by a vernier drive dial, a band setting capacitor,

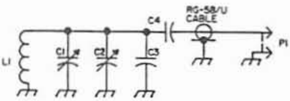
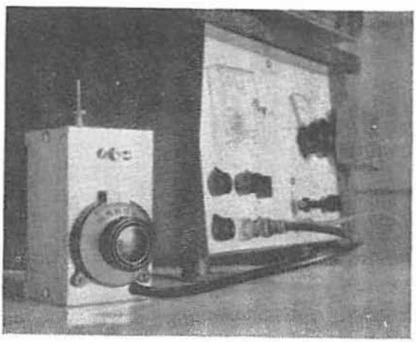


Fig. 1. Schematic of the tubeless VFO for six or two. C1 is the tuning capacitor, 3-25 pF with a shaft. C2 is the bandsetting capacitor, 4-50 pF. C3 is a 220 pF mica capacitor. C4 is a 150 pF mica capacitor. L1 is a ⅜" coil form with 8 turns of #18 Formvar on it.

which is variable, and a fixed mica capacitor so that the tuned circuit is rather high "C". The mica capacitor is choosen so that temperature will have minimum frequency effect.

Note also that the inductance L1 is wound on a form—ceramic in this case—so that the inductance will not vibrate mechanically and "sing" every time the unit is jarred.

Also the use of the crystal socket on the Clegg is impossible as it does not provide positive contact. Thus we used a BNC connector but for those who might not have a supply from surplus gear, the RCA audio plugs are convenient and adequate. The coaxial lead from the VFO to the rig should not be long—many suggest seven inches as a maximum—but this may be longer. I am using 15 inches. The shorter the better as this coaxial lead is a capacity loading across the frequency controlling tuned circuit.



The tubeless VFO feeding a Clegg 99'er.

First we mount all of the parts, keeping in mind short leads and rugged construction. This unit was rebuilt after making the mistake in trying to use a self-supporting inductance. The variable tuning slug is not needed, but as it is a part of the coil form, we did not remove it.

I found that 8 turns of 18 Formvar (enamel is ok) wire was about right so that the tuning capacitor covered the band from 10 to 80 degrees on the dial. Use a grid dip meter to regulate the band setting. The series mica and the cable load the tuned circuit so that when they are added, the band setting capacitor is backed off a bit. It was felt that no connector was needed at the unit, so that the RG58U was tied into the VFO and the outboard end was provided with the cable connector.

Note—for six meters the VFO should start on 12.5 MHz rather than 8.333 MHz a unit

for two should be on 12 MHz rather than 8.000 MHz.

Before putting the rig on the air, we suggest that you try the unit running into a dummy antenna such as a suitable lamp, until you are sure you are stable and within the band. It is easy to pick up the 12.5 MHz signal on a general coverage receiver. I find that signals on the air drift more than the apparent drift of this VFO. . . . W1DFS

Station Control Unit

The unit to be described has provisions for two band operation as well as two separate transmit and receive frequencies on each band.

The unit makes use of surplus parts and is very straightforward in its operation.

There are two rotary-ratchet relays in use, one is set up so that every other terminal is grounded. When this relay is stepped, it alternately energises or deenergises relays ry1 through ry3. These relays take care of the bandswitching function. Provision is also included for automatic switching of metering. The other rotary relay applies a series of pulses to crystal-can relays in the various transmitter and receiver units. The first step applies no voltage to the relays. The second step applies a positive pulse at 28 vdc to the relays triggering one set. The third step applies a negative pulse to the bank of crystal-can relays triggering one set and releasing the other. On the fourth and final step 28 vac is applied to the bank of relays triggering both sets. This works out very well in conjunction with a local repeater, allowing either direct contact or contact through the repeater.

A fourth relay Ry4 has the duty of switching the receiver voltage for muting as well as the metering and keying the PTT. This

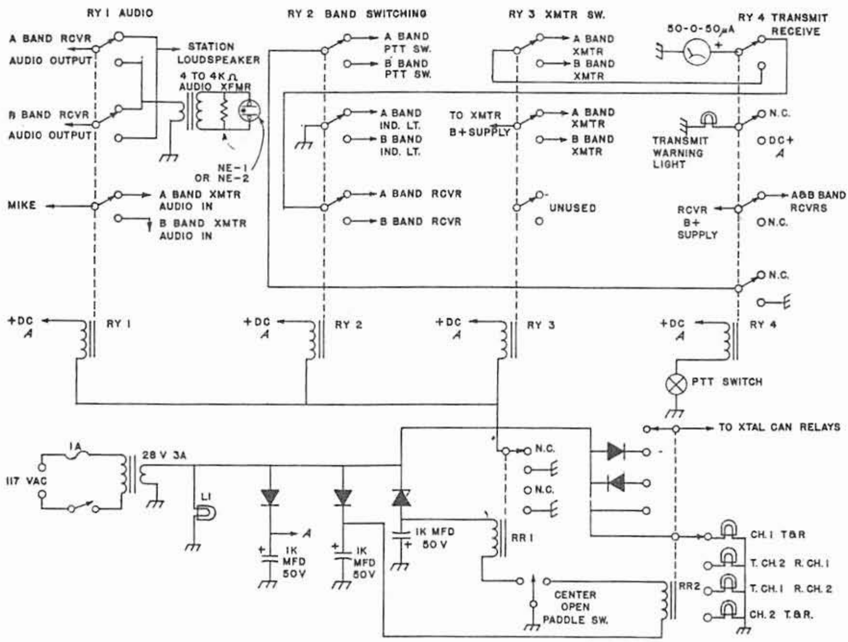


Fig. 1. The station control unit. RR1 changes bands each time the paddle switch is pushed to the left, RR2 changes channel setup in either band when paddle switch is pushed to the right. Lamps in lower LH corner of the schematic indicate which of four channel tuning schedules is in effect.

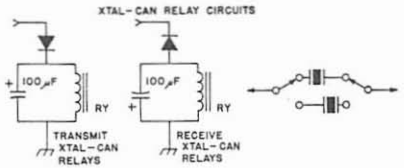


Fig. 2. Series diodes determine applied voltage polarity that will operate the crystal-can relays. With added capacitors, relays will operate reliably on ac, which is applied during some Station Control settings. Note relays switch both sides of the crystal circuit.

relay is keyed to ground through the PTT contacts on the microphone. The PTT circuits of both transmitters are keyed every time the PTT is energised, however only the selected transmitter is operational as the power is switched through a set of contacts on the band s selector relay.

Also included is a second band monitor. Both receivers are running continuously. One is feeding the speaker while the other is feeding an audio output transformer hooked up in reverse. If there is any audio present on the second band it will light 19.

Channel switching is done by means of small dpdt relays. These relays, due to their physical size are called "crystal-can" relays.

One is used in each transmitter and receiver and wired so that the wipers connect the crystal across the the crystal socket. The relay used in t this manner reduces problems, due to the fact that there is only one crystal in the circuit at any one time. One lead is connected in parallel with all other relays and goes to the wiper of Rry2. The other lead of the coil goes to ground through an appropriately polarized diode. It is well to have like relays keyed at the same time. That is both transmitter and both receiver relays keyed together. A provision is included for lamps to indicate which channel is in use at any one time and a chart is easily made to call out just what each lamp indicates.

The purpose of this is not so much for construction of exact duplicates but to open the doorway for thought and design to meet your own personal requirements. .WA7EVX ∅.

The Twixer

To add 6 meter coverage (50 to 52 mc) to a Heath kit two'er, it is desirable to get a rig which has as much of the Two'er's circuits as possible. Fortunately, by reworking the power supply a bit, one section of the Tx/Rx switch was freed to be used to switch the 6 meter antenna. The Tx/Rx switch will now serve whichever rig is on. Band switching is done in the filament line, and the tubes are wired to allow for 6 or 12 volt operation.

The receiver uses a 6U8, the triode half as a super-regenerative detector, the pentode half as an RF amplifier. The regeneration pot on the rear apron controls either the Two'ers detector or the new 6 meter detector. In my unit, setting the pot on 2 meters proved to be satisfactory on 6 also. The Two'er detector plate choke is now common to both bands as is the audio section.

The triode half of a 6BA8 function as a third-overtone oscillator to drive the pentode half which doubles to 6 meters. This allows the use of 8 mc crystals. We have found this transmitter to be quite adequate for local work. The Two'er audio section supplies modulation in transmit.

Changes

The addition and changes were done in four parts.

PART 1 Filaments and filament switch.

1) Add the dpdt slide switch between and below the Two'er tuning capacitor and Tx/Rx switch. Be sure this switch will clear the variable capacitor and the outside case.
2) Wire the Two'er filaments (as shown in **Fig. 1**) to the switch. The 6 meter filaments will be added later.

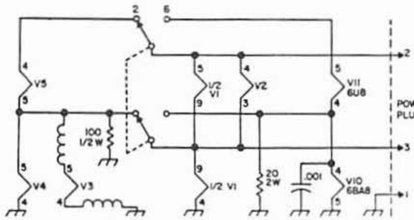


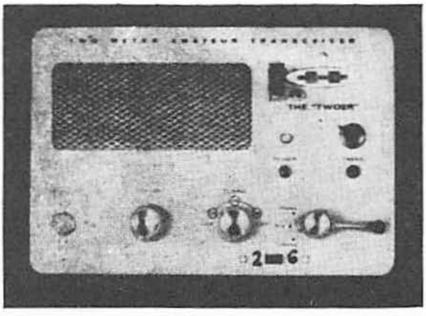
Fig. 1. Rewiring of the Two'er filaments.

PART 2 Tx/Rx switch, antenna jack, and power supply.

1) Move the wire from lug 2 of switch **Z** to lug 1 of terminal Q. (use longer wire)
2) Remove the wires from lug 3 of switch **Z**. One wire goes to lug 3 of capacitor I; remove this wire completely. The other wire goes to lug 3 of terminal AA; this wire now will go to lug 2 of terminal S.
3) Remove the output detector diode, terminal F, jack G, and associated wiring. Mount the type antenna fitting you intend to use in the vacant hole.
4) Add a heavy wire from lug 3 of switch Z to the new antenna fitting. Keep this wire away from the chassis.
5) Replace R14 with a 4 H 100 ma choke. Move C31 and C32 to make room for the choke.
6) Change R15 to a 2.2k 2W.

PART 3 Upper front panel additions.

1) Since most hams will be using junk box parts, **Fig. 2** only shows where the component should be centered.
2) Drill the necessary holes and mount the components (except the Receiver variable tuning capacitor).
3) See Fig. 4 for details on the receiver tuner. Mount the receiver variable.



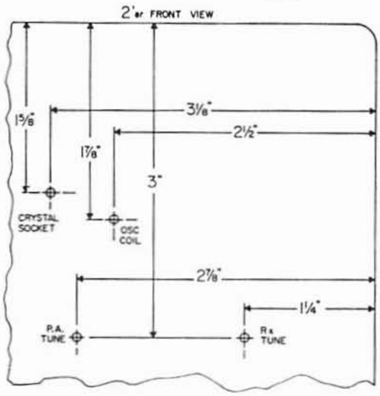
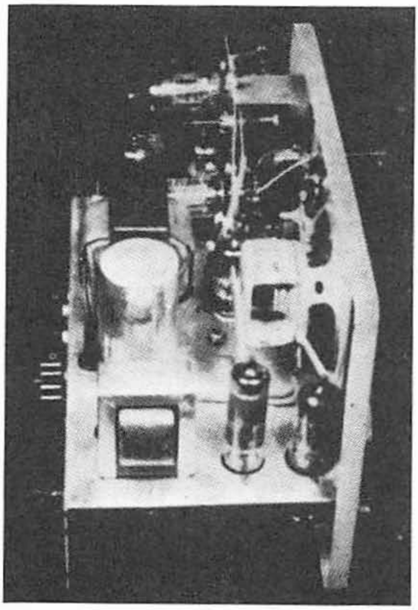


Fig. 2. Upper front panel additions to the Two'er.

4) Install L11 just above and behind terminal capacitor, the other end goes to C15 in the Two'er.
5) Install the .001 μf capacitor at L10. Also run a 22k resistor to lug 2 of terminal AA.
6) Run the other end of the .001 μf capacitor to the crystal socket. Also put in the 50 pf capacitor.

PART 4 New subchassis.

1) Make the new subchassis as shown in Fig. 5. The ½ inch lip will have to be notched to fit around V4. The panel should be bolted in 1⅞ inches from the Two'er front panel, after it is wired.
2) Install sockets for V10 and V11.
3) Wire up the sockets. All leads going to front panel controls, or to the Two'er circuit, should be left long enough.



Top view of the Twixer showing the subassembly in place.

4) Put the panel in place and drill convenient holes for mounting. Also drill holes for running the wires from this assembly through the Two'er chassis.
5) Make a strap to secure the upper end of this assembly to the front panel.
6) Secure all the loose leads from the new assembly (see Fig. 3).

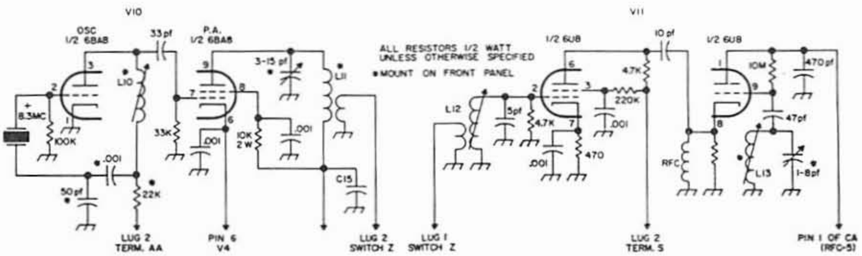


Fig. 3. Schematic of the added six meter components. Cathode resistor of the 6U8 is 470 ohms. L10 is 25 turns #28 enamelled of ¼ inch iron core form. L11 is 7 turns #16 tinned, ⅜ inch diameter, spaced one turn. Link is one turn #20 insulated. L12 is 6 turns #28 enamelled on ¼ inch iron core form. Its link is 1 turn #20 insulated. L13 is 6 turns #28 enamelled on ¼ inch iron core form. RFC is two layers #28 enamelled close wound on 3.3 k ½ watt resistor.

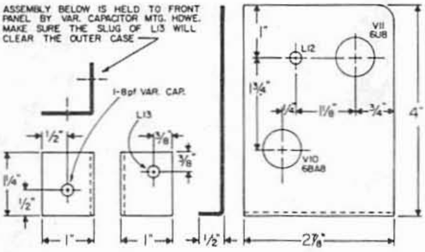


Fig. 4, left. Details of capacitor and coil tuning assembly.

Fig. 5, right. Details of the new subassembly. Front view of the Twixer.

TESTING

1) Put the filament switch in the 6 meter position. Turn on the power. If the filaments light, and there is no smoke, adjust the Two'er regeneration control of the regenerative hiss. Adjust L13 to get the tuning range to 6 meters. On a weak signal peak L12.
2) Plug a 8 mc crystal for 6 meters into the new crystal socket. Put the Tx/Rx switch in the Tx position. Adjust L10 for maximum output (use a grid dipper in the diode position) at 24 mc. Adjust the 3-15 pf capacitor for maximum 50 mc output (use a small pilot lamp for a dummy load).

That's it. You now have a Twixer Two'er.

. . . WØHMØ

Six-to-Two Transmitting Mixer

The trend today in VHF amateur equpment is toward use of commercial SSB exciters and adapters. But one thing missing among the many lines of equipment manufactured is a unit that will allow the amateur to use his 50 mc equipment on two meters.

Yet this can be done very easily and effectively without any modification of the six meter transmitter if you use a transmitting mixer and use the exciter to drive the mixer. Receiving can be easily handled by a simple converter which takes its local injection from the oscillator in the transmitting mixer unit via the oscillator output jack.

The mixer shown here (**Fig. 1**) gives tremendous supression of unwanted signals. It uses a 6360 tube as a mixer and a second 6360 as a class AB1 amplifier to give an output of 15 to 20 watts PEP. This is plenty of power to drive a linear or to use barefoot and many wonderful contacts have been made with this unit without any additional amplification.

Construction is very simple and easy it you follow the photos. Proper shielding between stages is very important to tame the unit so that it won't take off on its own as some mixers do. The shields can be made very easily from sheet copper or copper clad board.

L2, L3 and L4 can all be made from one piece of B and W stock by removing a single turn between windings. This makes a neat, easy-to-mount assembly.

This particular unit was built on a chassis which was designed so that a final amplifier could be added later. The room available will accomodate a 5894, 829B, etc. The chassis could be made smaller if desired.

The power supply shown uses a power transformer from a junked TV set. It works well and is easy on that ole pocketbook! The bias circuit is a clever system since it needs no additional transformer. The switch in this supply can be on the antenna relay and allow the mixer to be cut off during the receiving cycle.

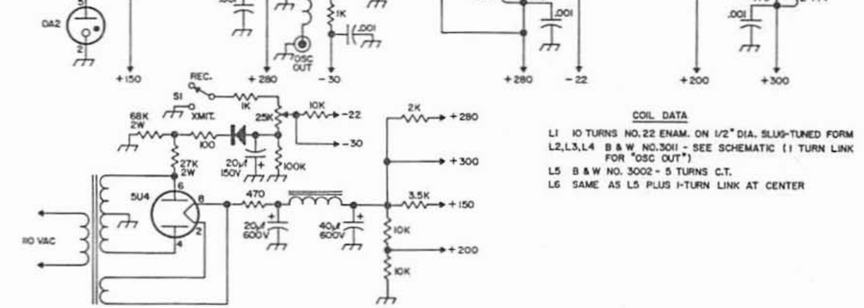
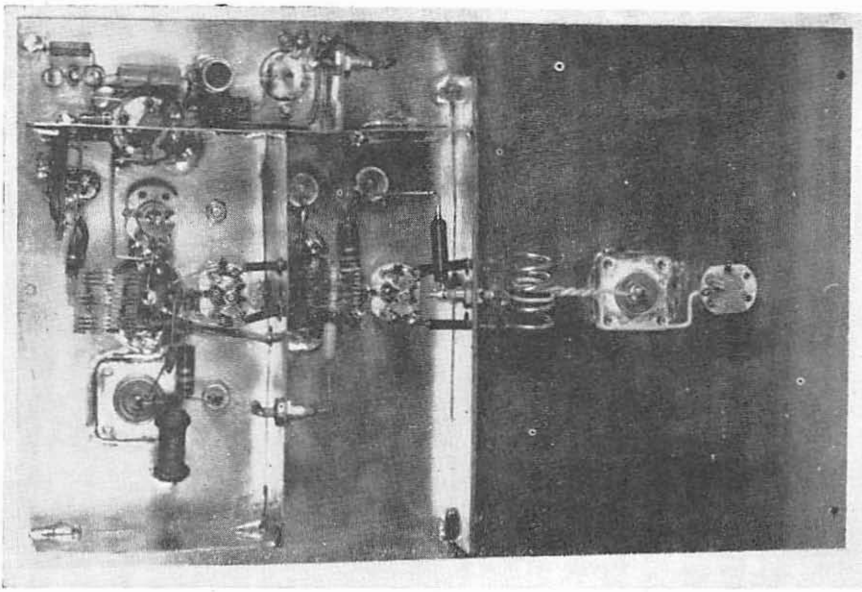
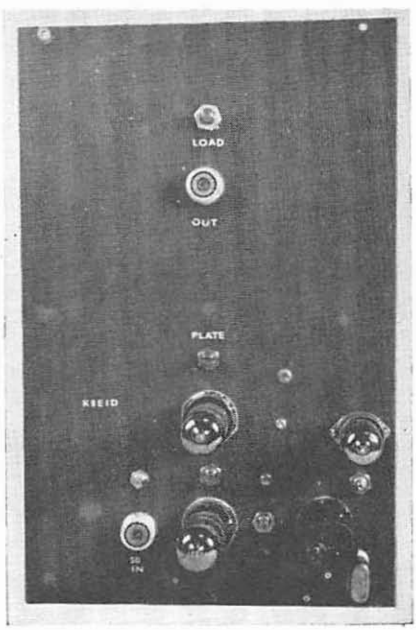


Fig. 1. Schematic of the six to two meter SSB mixer. B & W 3002 is two inches (5 cm) of ½ inch (8 mm) 8 turns per inch number 18 wire. It's the same as PIC 1728 and Air-Dux 408T. B & W 3011 has a diameter of ¾ inch (2 cm) and is 16 turns per inch (6 per cm).



Here's the bottom of the six meter to two mixer. The copper clad chassis plate is 5 x 6 inches (125 mm x 15 cm).



Top of the mixer. Tubes, clockwise from bottom center, are: OA2, 6EA8, 6360 and 6360.

Just remember that it should be open on receive and closed on transmit.

The voltages shown are operational voltages during transmit with S1 closed. These voltages will vary somewhat with different transformers in the power supply. The power supply is built on a separate chassis to minimize heat in the mixer unit.

This unit performs very well with six meter SSB transceivers. It is a very easy method of putting an SSB signal on two meters and it could also be used to put any six meter AM signal on two.

Have fun building and operating this fine unit. . . . K9EID

FET Preamp

Many amateurs come to the point where they need an extra preamplifier for wider coverage with their mobile FM operation. I have constructed several field effect transistor amplifiers for 6 and 2 meters which yielded many interesting results. Approximately twice as much gain may be achieved when using a field effect transistor in the grounded-source arrangement as compared with the grounded-gate configuration for the same bandwidth; however, neutralization is almost always required. By using a field effect transistor in the grounded-gate configuration, the amplifier is simple to build, gives adequate gain and bandwidth with a low noise figure and ease of tuning. The low feedthrough capacitance eliminates any need for neutralization. The only tuning after construction is to peak the two tank circuits for resonance. When the preamp is used in mobile operation, the supply voltage may be taken from the car battery.

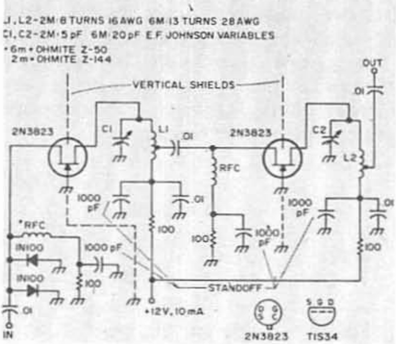


Fig. 1. Cascade preamp circuit, using two grounded-gate FETs, provides plenty of rf gain on 6 or 2 meters. Frequency-sensitive values are listed at the upper left portion of the diagram.

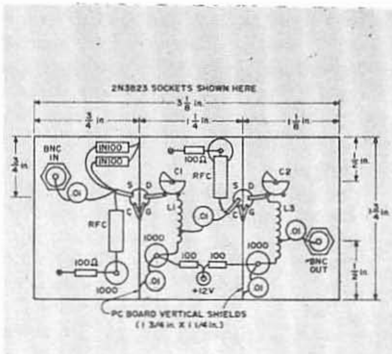


Fig. 2. Sketch shows layout of FET preamp. Note use of shield walls between stages.

The schematic of Fig. 1 shows the 2N3823 (or TIS 34) field effect transistor cascaded in the common-gate configuration. An input tank circuit was tried and replaced by a simple rf choke to provide the rf input load. The low input impedance into a grounded-gate configuration tends to broaden or swamp any input tank circuit. The biasing resistor is bypassed to provide the rf ground. Two 1N100 diodes were placed back-to-back at the input connector to prevent possible overload damage. Poor isolation, especially in the antenna relay, could easily destroy the input transistor.

Construction

The amplifier was mounted on a piece of copper-clad printed circuit board. The board, with the copper on but one side, is cut to length and drilled as shown in Fig. 2. The general layout may be increased if parts appear too cramped. Notches must be cut in the vertical shields for the transistor sockets. The boards and component leads are then cleaned with steel wool to prepare a good soldering surface. After the sockets

are mounted, the vertical shields are soldered in place neatly and evenly using a small soldering iron. The standoff button bypass capacitors are soldered firmly to the board. All ground connections are made by directly soldering the part down on the copper.

The 2 meter coils are wound on a ¼ in. diameter rod using 8 turns of 16 AWG enamel-coated copper wire. The coils are spread to ¾ in. long and tapped 2 turns from the supply voltage end. Each 6 meter coil is wound on a 3/8 in. diameter rod using 13 turns of 28 AWG wire, tightly spaced and tapped 2½ turns from the cold end. Care must be taken when soldering the leads to the Johnson capacitors. The stator plates are held in position by solder during manufacture and may fall apart when heated. Maximum capacitance values of 5 pF for 2 meters and 20 pF for 6 meters were chosen for the variables so that they would be in their mid-position at resonance. The output tap may be varied

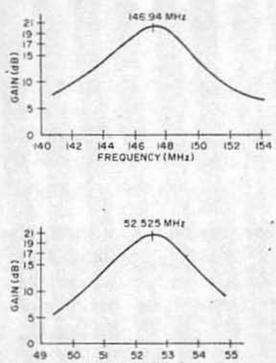
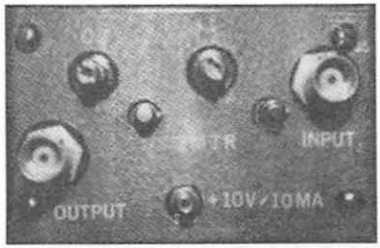


Fig. 3. Gain-bandwidth curves for 2 and 6 meter versions of the FET preamps. Note that gain peaks at about 20 dB in both instances.



to determine bandwidth and gain. The positions shown here are not critical, but are a compromise for broad bandwidth.

A CU-2101A Minibox is drilled to allow passage of the connectors, sockets, and capacitor shafts. The printed circuit board chassis is then bolted to the Minibox top and labeled with dry transfers or decals.

Performance

With a 12V supply, the preamp draws about 10 mA total current. The two capacitors are tuned to resonance simply by peaking on noise. Figure 3 shows the response characteristics of each preamp. From the results shown, the 2 meter amplifier needs only to be peaked on 146.94 or 146.34 MHz, the most populated FM channels, for 20 dB gain. With a 3 dB bandwidth of approximately 3 MHz, the amplifier has at least 16 dB gain over the entire 2 meter band when peaked near 146 MHz. The 3 dB bandwidth of the 6 meter amplifier is only 2 MHz. When peaked at 52.525 MHz, the amplifier will have greater than 20 dB. The addition of either preamplifier should help to solve many of the sensitivity problems, especially with the older equipment.

. . . WA4WDK/2 ■

Simple 6 & 2 Amplifier

There are three things that loom up large dollar-wise in this six and two meter amplifier: the tube socket, the blower and the tube. However, if you have a 4CX250 or two lying around and are thinking of the possibilities of a quarter kilowatt on six and two, this design allows you to switch bands with only one pole and one throw. You could also use a surplus, inexpensive, 4X150 in this circuit.

The circuit in **Fig. 1** has been used successfully up to 200 mc here. It is very hot on two meters and even more so on six. It can be seen to be a trough line pi network on two meters, changing to a good old coil type pi network on six. The switch is a slightly reworked (solder on some strap copper leads) knife blade copper switch with a porcelain base and it sure does the job. Used to sell for 50¢ in all the hardware stores. Maybe still does.

Note in the circuit that the RF plate choke is at the low (for RF) end of the plate inductor, L1. This particular choke has a slight absorption spot near 70 mc which does not bother in any way on six and two meters, but can be a nuisance when working for complete coverage from 20 to 150 mc.

RF output circuit

We would advise getting a good socket with the screen bypass built in. This capacitor is in a circular form around the tube, and believe me, there is nothing like a round flat disc for VHF and UHF capacitors. During several weeks just spent on this unit running up and down between 18 and 170 mc many times with all kinds of coils, switches and capacitors, not once did it self oscillate. And this is with no neutralizing at all. The built in screen bypass is really doing its job of isolating the input from the output circuit. It also has another job to do as you will see.

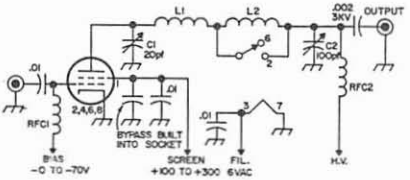


Fig. 1. Schematic of the 4CX250 amplifier for six and two meters using single pole switching.

A word about RF currents in screen-grid coaxial tubes is in order here. Electrons, as is well known, flow happily from the cathode of these tubes over to the plate, greatly attracted and speeded up on their way by the high positive plate voltage. Field theory says that an electron finding itself in a vacuum between two conductors, one positive and the other negative, will accelerate and slam into the positive conductor at a remarkable number of miles per hour, if the voltage is high. In fact they will get well up towards the speed of light with many thousands of volts.

However, they do *not* travel at the speed of light in tubes in amateur use, and thus are subject to the much talked about transit time effect. The point here is that in order to know what is going on RF-wise in VHF and even more so in UHF, you should differentiate between the electron flow and the RF current flow. A positive *wave* from the RF drive on the grid causes electrons to go through the grid. With a few landing on it of course. At the moment they go through the grid they see the screen ahead of them with all that beautiful 250 volts positive on it and away they go like dogs after the electric rabbit. Same thing happens all over again as they go through the screen, only this time they see 1500 volts (minus the 250 of the screen) and really get moving. (This is where the blower comes in, by the way). Arriving at the plate these electrons, being little particles of negative electricity, cause the plate to go negative. Now, watch out. The wave-front created on the plate travels along the plate line L1 at almost exactly the speed of light, reaches the cold end of the trough-line about a quarter cycle later and then starts back again, reaching the opposing conductor that is, the conductor in the tube that is RF-wise attached to the walls of the trough line, as is right and proper. But what is this opposing conductor? Is it the cathode? Nope. The grid? Guess again. It is none other than the highly by-

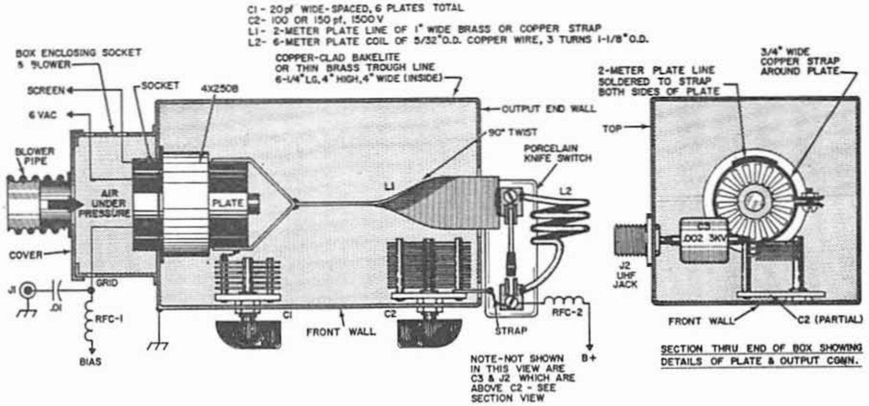


Fig. 2. Top and side views of the 4CX250 amplifier.

passed screen. The RF waves in the trough line cannot get through the screen. The screen is thus the second most important element for the RF output, not the cathode.

The cathode leads need to be short for the input circuit however. So, the moral is, pay attention to the plate-screen RF circuit here for those hundreds of watts out you are looking for.

High power VHF trough lines

Getting down at last to the actual construction ("tin cutting") we see in **Fig. 2** a top view of the trough line, switch and 6 meter coil. The socket is mounted in the center of the front end which is 4 inches by 4 inches thin brass .022 to .025. A flat box is also mounted under the socket with a cover containing the blower pipe hole. This cover is fastened with four screws, which allows work on the socket later if needed. A well insulated and spaced low capacitance grid lead is brought out to RFC 1 and the grid input capacity. This must be air sealed of course, as well as all others going through the socket box, in order that the air from the blower will be forced *through* the socket, which is designed for that purpose. The air continues on through the plate fins after going through the socket.

The tuning capacitor C1 should be able to take care of the B plus voltage of some 1500 volts, or higher if you're that anxious. The RF voltage may be considerably higher than 1500 if the plate circuit is operated unloaded. (Not advisable for any length of time!) Do not make the usual pencil test unloaded without having that pencil on a stick! Insulated! The RF really rips out but plenty. Not just a little spark but a *roaring arc*.

The actual plate connection is a thin copper strap (soft copper) with its ends bolted together. The plate line, composed of two 1 inch straps at the plate which are joined together about 2 inches from the plate, making a single strap from then on, is soldered to the plate strap in two places as can be seen in **Fig. 2**.

Fig. 2 also shows the positioning of the output capacitor C3 and output jack J2. C2 and C3 are actually *inside* the front trough line wall. The knife switch is mounted on a wood block about 1¼ inches which brings it up to level of the plate tank line (2 meters) which is positioned in the middle of the 4 inch high trough line. The flat handle of the knife switch may be extended through a front panel. Insulated! A panel is advised, as the switch, L2, C2, and one end of C3 are all at high voltage. We used bakelite shaft extenders and mounted the front panel, 3/16 inch white plastic, about one inch in front of the front wall of the trough line. RFC2 is 80 turns of No. 20 solid, covered wire, 2¾ inches long, wound on a ceramic form ½ inch O.D.

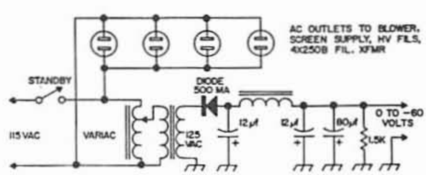


Fig. 3. Bias supply for the amplifier.

That about does it except for a few details. The output end wall and the socket wall are of thin brass, .022, some 4 by 4 inches square. The RF output jack is mounted on a strap which is soldered across the top of the trough line. You can also close the top in with a brass cover if you wish, and the efficiency will go up a percent or so on 2 meters. I have not done this yet. The output end wall has a large hole cut out in the middle (not shown) for the cold end of the 2 meter plate line to be led outside to the switch. Note that when using a pi network this is only cold to the extent of being near 50 ohms..

Again a word of caution. Tune this rig up frequency-wise on low voltage, about 250 to 500 volts.

Driver and power supplies

So far I have only driven this amplifier with 50 watts. The RF drive power, that is, grid input to the 4X250B, is listed as from 0 to 2 watts in the handbooks, so take your choice as to drivers. Even a Sixer should do it. I have used various powers on the driver and it seems to settle out around 10 to 12 watts DC power to the driver, with the untuned grid circuit, cable, and driver being used here. The cable connecting the driver at the moment is about 5 feet long. With an untuned grid circuit this cable can change the RF voltage on the grid up or down a considerable amount as can readily be seen. At or near a quarter wave length and tuned by the grid-cathode input capacity of the 4X250B there could be a lot more RF on the grid than with a half wave on the line where one could expect something like the exciter link voltage to be found on the grid.

Exciter drive power and modulation of the driver should be adjusted while listening to your own voice or with a scope. You'll soon see why when you do it.

Bias supply

We had some trouble at first with a large jump in grid bias voltage under RF excitation and modulation. This was due to the bias source not being "stiff" enough, and was remedied by the bias supply shown in **Fig. 3.** Using this supply the negative voltage was 70 without RF drive, 80 with drive, and about 85 when modulating the driver. The Variac shown in the primary of the bias supply is of course a better method of regulating such a supply than a potentiometer network in the DC output.

Screen supply

Nothing fussy about the screen supply. Just 0 to 300 volts, 50 ma, adjusted by another Variac. The "Turn-On" switch has a 115 volt outlet which goes to the HV Variac, which is in the primary of the HV transformer. This allows the screen and HV to be turned on at the same time.

HV supply

Again nothing special. We used an old KW job, tapped down to 1500 volts AC maximum. And of course, another Variac! Caution! Do not operate the tube with the screen on the plate off! All those electrons which are supposed to go to the plate land on the screen and wowie, what screen current! Very bad for a $38 tube.

Results

First, be sure that there is at least 50 or so volts negative bias on the grid and that it can be varied. Set the screen for about 100 to 150 volts and the plate for say, 500 volts. This is without any RF drive. No plate current should show. Drop the bias down carefully. Plate current and screen current should begin to show. Adjust the plate current to about 100 ma for a start. Then apply drive on 6 meters using a dummy load, for example a 100 watt bulb in J2. Plate current should jump up to some 200 ma. A good plate dip should now show under resonance on rotating C1 with C2 at maximum. Adjust C2 for load, returning with C1. This pi network should adjust nicely from a large plate dip and little RF output with C2 at maximum, through a maximum RF out at the proper setting, and on to very flat or no tuning at all with C2 at minimum. This last is *not* the place to leave C2 and plate current will be heavy. A little practice will show you how to operate the pi net. The maximum RF output point is very noticeable over quite a narrow range at or near the proper setting for C2. On 2 meters of course there will be a great deal less of C2 for maximum output.

There are several adjustments for an AM linear. The amount of RF drive is important; the fixed bias on the grid; the amount of driver modulation; the screen voltage; and the

RF loading of the plate circuit. The effects of these are readily heard while listening on the "system". All handbooks on AM linears mention the adjustments as "critical". Don't forget that an AM linear is 66% efficient RF-wise under driver modulation. Not 33% as sometimes mentioned by handbooks. Some of them (handbooks) have only committed "sins of omission" by just mentioning the 33% and not saying anything about the 66%.

. . . K1CLL

VHF Band Scanner

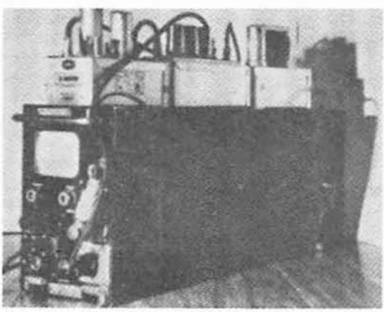
The pan adapter has received a considerable amount of publicity and does a fine job for the HF (160-10 meters) ham. The pan adapter that covers 250 KHz is usually sufficient. The VHF ham, however, may want to observe 2 MHz or more of the band.

The band scanner to be described will cover the full 4 MHz of the 6 and 2 meter bands, if desired. The band scanner is sometimes referred to as a spectrum analyzer.

Pan Adapter vs Band Scanner

There is very little difference in the units. The pan adapter has the same input frequency as the *if* of the receiver and is usually connected to the receiver mixer plate. This arrangement keeps the received frequency centered on the shield of the cathode ray tube. The selectivity of the *rf* stages of the receiver reduce the signal strength of the signals either side of the center frequency. The pips, or displays, are progressively smaller as they are farther from the received frequency.

The band scanner uses a typical crystal controlled VHF converter with the same output frequency as the band scanner input. A two or three stage *if* amplifier is usually required between the converter and the band scanner to give a good distinct display of weak signals. An *rf* tap for the receiver can be made at the input or output of the *if* amplifier. The band scanner display is independent of the receiver tuning. If properly adjusted, the scanner will have nearly equal sensitivity over the entire band. The scanner cathode ray tube shield can be calibrated for direct frequency reading.



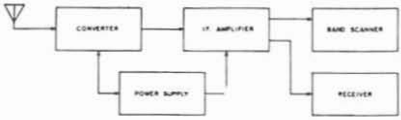
VHF band scanner. On top from front to rear are the converter, *if* amplifier and power supply.

The Units

Band scanners are available on the surplus market so cheap that there is no advantage in constructing one. The scanner is easily repackaged to give it a neater and 'civilian' look, if desired. The conversion information that is sent with the IP 274/ALA10 or IP 69/ALA2 band scanner covers changing the power supply to 60 Hz (the original is 400 Hz) and changing the input to 14 MHz. All my VHF converters have 28-30 MHz output so we did not change the scanner input frequency. The IP 274/ALA10 and IP69/ ALA2 scanners have the four standard oscilloscope controls: intensity, focus, horizontal position and vertical position. The scanner controls are; sweep limit, width, center frequency and gain. We removed the front panel power plug and replaced it with a plate and an ac outlet. The outlet is connected through the switch so the converter and *if* amplifier will be turned on and off with the scanner.

If you want to cover only 2 MHz of the band the center frequency control may not center the scan. We use a converter output of 28-30 MHz so we injected a 29 MHz signal into the scanner input then turned the center frequency control to bring the pip as close to the center of the shield as possible. We backed the control off about ¼ turn to allow for calibration then adjusted L 104 (scanner sweep frequency coil) to center the 29 MHz signal on the cathode ray tube shield. Touch up the scanner input and *if* coils for equal sensitivity at 28 and 30 MHz.

The converter can be constructed or purchased. A poorly built converter can give false pips as the scanner will show any *rf* signal in the sweep range. The most common sources are self oscillation of a tube or transistor or exces-



Block diagram of band scanner and associated equipment.

sive oscillator injection. Be sure your converter is adjusted for flat response over the sweep range.

We used a surplus 30 MHz *if* amplifier. Stagger tuning this amplifier should give it sufficient band pass and still have enough gain to operate the scanner. There are transistor and tube 14 and 30 MHz preamplifiers in the handbooks. These preamps will, of course, work as an *if* amplifier. The *if* amplifier requirements will depend, to a considerable extent, on the quality of the converter. The *if* amplifier should be tuned for flat response over the sweep range. Generally, an amplifier with 20-30 db gain is sufficient. The schematics show both capacitive and inductive coupling for the receiver *rf* tap at the *if* amplifier input and output. I use capacitive coupling at the output. If your receiver does not have an *rf* stage the local oscillator may radiate enough signal into the antenna input to give a false pip on the scanner. Connecting the receiver at the *if* amplifier output will minimize this condition. The receiver *rf* tap at the *if* amplifier input would be used by those that have a high quality receiver and the *if* amplifier would not aid the receiver.

Assembly

Due to the variations in the converters and *if* amplifiers that can be used with the scanner, and the simplicity of hookup, step by step instructions would be of little value. The interconnecting *rf* cables should be as short as possible. Use good VHF practice and no difficulty should be encountered.

Power supply requirements will depend on the units used.

Operation

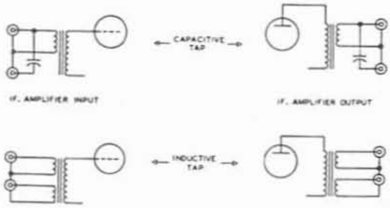
A band scanner will show the band activity, or lack of it, without tuning around and searching.

If you have more than one converter and antenna for a VHF band you may want to use separate converters for receiving and scanning. I use this system. The receiver coupled to the scanner lets me check out any other signals that I see without interfering with the QSO in progress. I put a relay in the scanner antenna lead and remove the converter B+ voltage when transmitting. The antennas are quite close together and the transmitter has a maximum output of 200 watts so I wanted to protect the converter from possible damage.

Some transmitters used in our local two meter net are crystal controlled and slightly off frequency so we have to tune for them. The scanner lets me see when they are on without wasting time tuning between transmissions to see if they are on.

Other Uses

For our CB friends who might be interested in a band scanner we would recommend a good *if* amplifier as no converter is needed. If, however, you plan to build a fancy scanner and calibrate the shield to show the channels, a converter is required. The converter will give you additional selectivity the same as a dual conversion receiver. Use a converter with a 14 MHz output and a 14 MHz *if* amplifier. There would probably be a small pip at 28 MHz from the converter oscillator. This would be out of the CB band so if you narrow the sweep to cover just the CB channels the pip would not show. Align the converter, *if* amplifier, and scanner for flat response over the sweep range as in the ham version. We would recommend a separate antenna. You might get enough isolation in the antenna relay so you



For capacitive tap use the smallest capacitor that will give adequate coupling. Start with about 20 pf and increase or decrease as required. For inductive tap make tap identical to the input or output winding and use minimum coupling. If input or output uses tapped coil use capacitive coupling. Some units may work better if band scanner and receiver tap are reversed.

could see your own signal when transmitting. We have not been able to do this with higher power.

Conclusion

Home brew construction of the converter and *if* amplifier is not recommended for the beginner as critical broad band alignment is required for satisfactory results. The band scanner has excellent broadband characteristics (max. 10 MHz) and alignment is not difficult if done carefully.

...WA8OIK

220-MHz Converter for Pocket Receivers

This unit is a low cost, two-transistor converter for use on the 220 MHz band, using any of the "police band" FM receivers that cover 146 to 180 MHz.

A recent proposal to open up 220 MHz for no-code hobbyists prompted the building of a foundation converter as an almost instant means of seeing what could be done today with low-cost solid-state 220 MHz rigs. The Allied-Radio Shack Model A-2587 was used as the i-f, discriminator, and af, on about 170 MHz. This is the output frequency of the converter being described when using a 50 MHz crystal in the oscillator.

The A-2587 receiver uses a miniature *telephone* jack for the 50Ω antenna connection, but as long as it works, who is to say no? The insertion of this "antenna plug" into the antenna jack on the receiver also cuts off the extendable antenna very nicely.

After removing the telephone plug from one of those little plastic-wrapped white earphones that always accompany a Jap receiver, we converted it to an "RCA phono" adapter, making up the 170 MHz connection between the converter and the receiver.

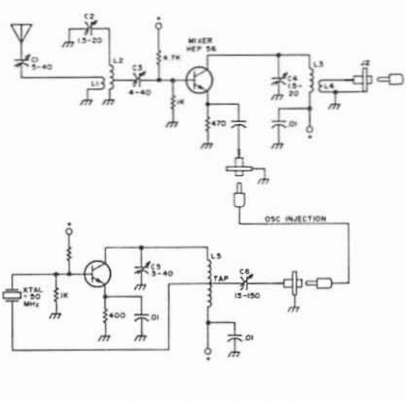


Fig. 1. Schematic, 220 to 170 MHz FM converter.

Figure 1 shows the converter circuit using a Motorola HEP 56 transistor, good for 750 MHz use, as the mixer, and a HEP 55 for the 50 MHz oscillator.

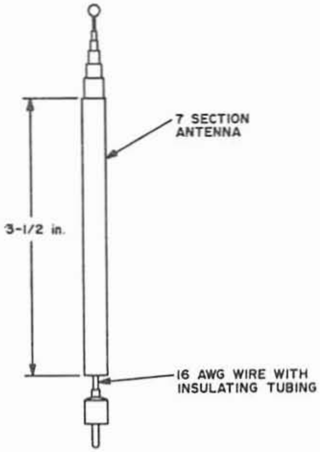
No attempt to achieve low-loss high efficiency was made, because the later installation of one or more low-noise figure rf stages is assumed.

At any VHF shack with a crystal within the 48 to 54 MHz range on hand, this unit can be assembled, wired, and tested easily in a day. The only thing to watch for, as always with an i-f near the signal frequency, is oscillator harmonics getting into the front end. The third harmonic at 150 MHz is pretty loud when you do tune across it (which you do *not* need to do, by the way). This harmonic can be dropped 20 to 30 dB by use of a series 50 MHz filter in the oscillator injection line, but was not found necessary here.

A small minibox will contain all the parts for this converter if you want to make a permanent unit out of it. It can also be made to fit flat on the back of the A-2587 receiver case if you want.

Generous use was made of Arco trimmers, and hand-wound coils did the rest, with nothing critical showing up, except that emitter oscillator injection was a *must*. Base injection at 50 MHz into a 220 MHz mixer did not work well at all.

A signal generator, 170 MHz tuned circuit (see Fig. 2), diode detector, and voltmeter were used to tune up the circuits and adjust the couplings. If you try and use the receiver as the i-f while doing this, you may succeed, but we find that the sensitivity tends to mask the desired results. Suit yourself on that. When you get a good solid dc signal out of the diode tuned to 170 MHz your converter and i-f output circuit are really working.



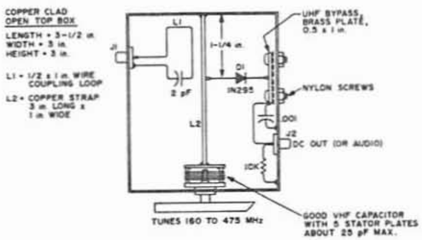


Fig. 2.

The 170 MHz diode detector is shown in Fig. 2. It also tunes up to 450 MHz, and will go down to 144 as well with slightly smaller dimensions and a 35 or 50 pF capacitor, thus covering three amateur bands.

Coils for all schematics are listed in the following chart:

Coil	Wire No.	No. of turns	Length of coil	Diam. of coil	Position
L1	22 insul	2	¼"	3/8"	End of L2
L2	18 bare	3½	½"	3/8"	
L3	18 bare	4	¾"	3/8"	
L4	22 insul	2	¼"	3/8"	End of L3
L5	24	15	3/8"	on 6/32 paper tube	Tap in center

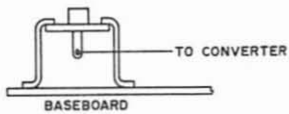


Fig. 3. 220 MHz breadboard antenna.

. . . K1CLL ■

220-MHz Converter

The 220 to 225 mc band in many locations is subject to strong image signal problems which can be reduced greatly by using a pair of high Q circuits in the antenna feeder. An antenna filter of this type suitable for transmitting and receiving service is shown in **Fig. 1.** It consists of two high Q circuits capacity coupled together at the tuning end of each line and loaded down to a working Q of about 25 for 50 ohm coaxial input and output lines. This loading is chosen by the position of the coax jack taps on each flat plate line near its grounded end. A tap point 1.5 inches from ground end seemed to function well over a large portion of the 220 mc band. The circuits are tuned to resonance by spring brass plates with adjustable spacing to the flat plate line at the "hot" end. The coupling capacitor is at this end also and consists of an insulated U shaped metal bracket as shown in **Fig. 1.**

The coupling depends upon the spacing at the ends so some adjustment can be made by bending the sides of the U bracket or by making a new one with more or less length between the sides of the U. Probably a better coupling scheme would be an aperture coupling at the high current end of the lines as was used in the 144 mc circuit unit previously described. The center shield with both sides grounded would then be about 8 inches long, also grounded at the tuning capacitor end. The aperture would be a 2 inch gap (approximately) at the coax jack end, making a total aperture opening of 2 by 3 inches in size for coupling the two lines together. This would eliminate the coupling capacitor U shaped bracket at the opposite end of the lines. An aluminum chassis, with cover, 10 x 4 x 3 inches in size encloses the flat plate lines. This with the center shield forms two air gap strip lines of high Q design, perhaps in the neighborhood of Q = 1000 unloaded. With loading and coupling, the Q is around 25 which would mean a loss of about .5 db for the complete filter. This loss would mean about half a decibel loss in NF for receiving and at the same time an efficiency in this filter of over 90% for either transmitting or receiving. The air gaps and design should make it suitable for KW operation though the heat loss might make it advisable to use copper plate lines and shields for lower losses. When the heating effects become readily apparent at very high power operation, the coupling and tuning capacities will change. Aperture coupling with copper or silver plated brass construction would then be indicated. The aluminum construction is suitable for antenna inputs of up to 200 watts with negligible heating effects.

220 mc converter

The new TIXMO5 transistors were used in this converter to reach a NF of about 3 db. At

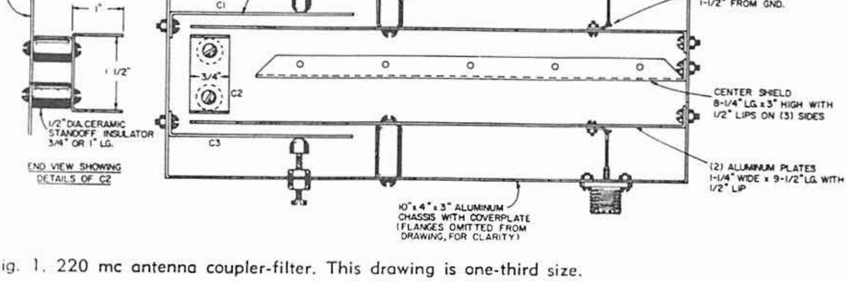
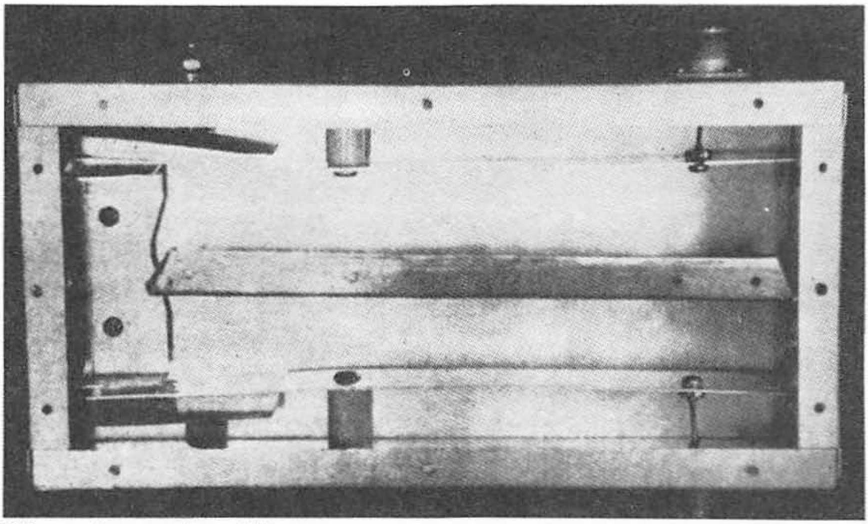


Fig. 1. 220 mc antenna coupler-filter. This drawing is one-third size.



220 mc antenna coupler and filter.

220 mc, either neutralized common emitter rf stages or un-neutralized common base circuits, may be used. The former has more gain, slightly better NF, but is more complicated and uses more parts. The common base circuit was used in the unit shown in the photographs and in **Fig. 2** and is suggested for general use. One of the older 220 mc converters here was rebuilt several times and wound up with the circuit shown in **Fig. 3**. With TIXMO5 transistors, it did have a little more stable gain and a fractional db better noise figure but the "rats nest" wasn't suitable for photographing.

The circuit of **Fig. 2** consists of two grounded base rf stages, with forward gain control separate from the converter, 2 by 6 inch copper clad board. This control can be set for best NF, which is below the oscillation point in the rf amplifiers. This type of rf amplifier is regenerative and there is no easy way to neutralize the stages; however, a variable gain control with screw driver adjustment solved the problem. 220 mc is apparently near the upper frequency of common emitter, neutralized rf stage operation so there is little choice between the circuits shown in **Figs. 2** and **3**.

The mixer stage can be either base or emitter input for signals and the emitter or base

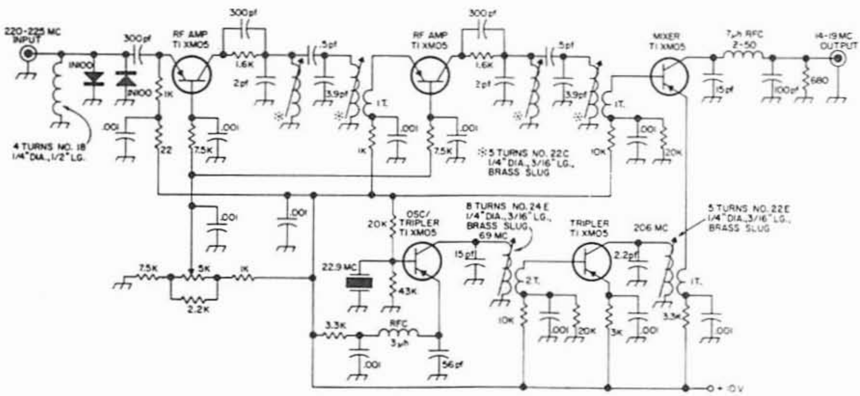
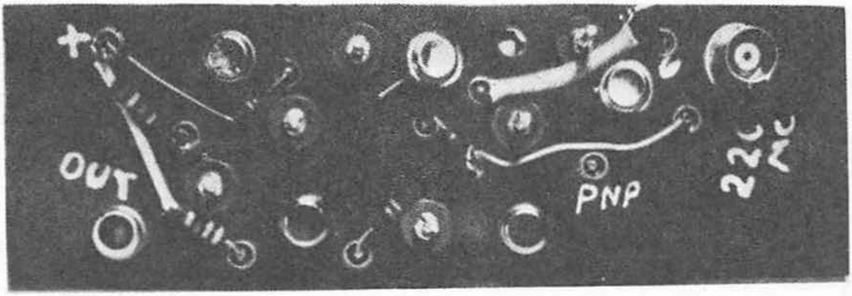


Fig. 2. 220 mc converter with common base amplifiers. This circuit is recommended for general use because of ease of adjustment and simpler construction.

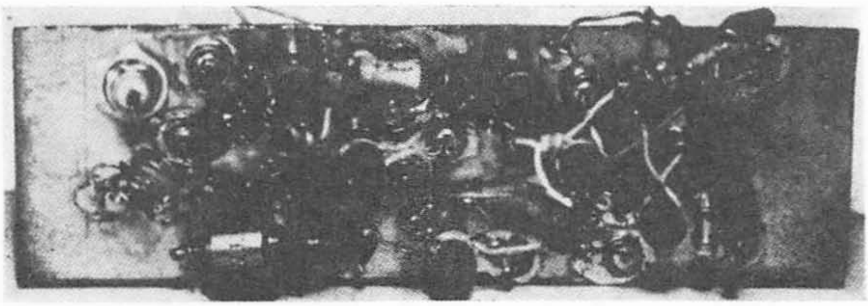


Top view of the converter in Fig. 2. The large transistors were replaced by TIXMO5's for better noise figure after this picture was taken.

used for oscillator injection. The input impedance at frequencies above 200 mc is not too different for base or emitter inputs. The collector circuit is broadly tuned to 16 mc with a pi network to cover 14 to 19 mc, the if signal range. Fixed inductance and capacities are suitable here with the 15 pf input (high Z end) the only critical value. With other transistor types having higher output capacitance, a smaller value than 15 pf would be needed and an adjustable 5 to 18 pf capacitor should be used.

The oscillator multiplier chain has two transistors, one as an oscillator-tripler and the other as a tripler to obtain 206 mc output from a 22.889 (or 22.9) mc overtone crystal. The emitter circuit is resonant between 22.9 mc the third overtone, and 7.6 mc the fundamental frequency of the crystal. This prevents 7.6 mc oscillation and causes 22.9 mc oscillation at the third overtone frequency. In turn this is multiplied by three times to approximately 69 mc in the collector circuit. The 56 pf capacitors in the emitter produces regeneration at the output frequency, resulting in good output to drive the second transistor tripler stage to 206 mc. This 206 mc power is coupled into the mixer emitter for mixing the 220 to 225 mc signals down to 14 to 19 mc, the output signal from the converter. The pi network transforms the high impedance of the mixer collector down to 50 or 75 ohms coaxial line output for connection to a receiver tuning the 14 to 19 mc range.

The input transistor is protected from overload by two diodes across the self resonant coil input circuit. These diodes were IN100 diodes which are not as good as fast computer diodes for this purpose but do a fair job since they are low forward resistance types suitable for VHF work. If better diodes of low shunt capacitance (at zero bias) are available, use them since transistors have much longer, low NF, life when not overloaded by transmitter signals leaking thru the coaxial antenna relay. As the operating frequency is increased, antenna relays are less effective in isolating the receiver from the transmitter. Very fast silicon type computer diodes generally have low enough capacitance to work as protective de-



Bottom view of the converter shown in Fig. 2. The drum shaped object in the lower left is the crystal.

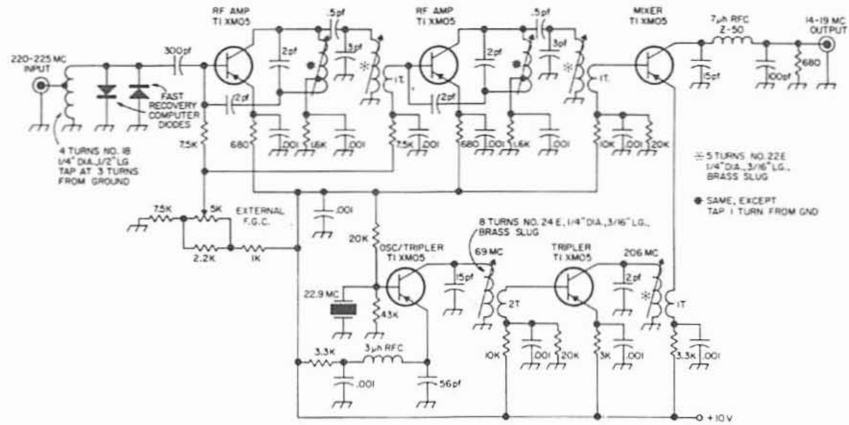


Fig. 3. 220 mc converter with neutralized common emitter amplifier stages. This converter gives a better noise figure and higher gain than the converter in Fig. 2, but is harder to adjust.

vices up to above 432 mc. A few germanium diodes rated for VHF with at least a 20 ma at +1 volt rating are fairly good at 220 mc.

A signal generator and noise generator are both desirable for use in aligning the converter for best weak signal reception and best NF. Oscillator operation can be roughly checked by listening to the hiss level in the if receiver when shorting out the oscillator or tripler tuned collector coils. The mixer noise in the receiver should be louder when the crystal oscillator is functioning. Too great an increase of noise may indicate excessive oscillator injection into the mixer or "blocking" type of oscillation in the crystal stage. The input coil turn spacing or even the number of turns may need adjustment for best NF and weak signal reception. Some protective diodes have greater or less zero bias shunt capacitance, which would mean that the input coil must be adjusted so it resonates at or near the low end of the 220 mc band. The transistor loading makes it very hard to "grid dip" adjust this circuit, so a noise generator is of great help at this point. The interstage slug tuned coils and the "gimmick" coupling capacitors (a twist or two of plastic covered 24 or 26 wire) can be adjusted for maximum gain and best coverage of 220 to 225 mc. In case the converter is to be used mainly at some spot frequency such as 222 mc, the coupling capacitors between tuned circuits can be of very small capacitance and all tuned circuits peaked up at that spot in the band. . . . W6AJF

VHF Transmitter Modification for CW

Many DX contacts on the VHF bands are missed because of the lack of CW activity. This dearth of CW is usually due either to unwillingness on the part of the operator to give it a try, or because many rigs, commercial and homebrew, just don't have provision for CW operation, even in this age of enlightenment.

The transmitter I modulated was the Tecraft TR-20, 220 MHz rig. However, the same approach can be used on many other rigs. The parts required are a DPDT toggle switch, closed circuit key jack, 7 pin miniature tube socket, .001 mF disc ceramic capacitor, OA2 VR tube, and a 15K, 10 watt adjustable resistor. Inspection of the chassis and the photographs will show the location of the components. The only critical point is to position the key jack as near as possible to the cathode pin (pin 2) of the final 6360.

The Phone-CW switch is wired so that in the Phone position the rig operates normally; in the CW position the modulation transformer secondary is shorted and the cathode circuit of the 6AQ5 modulators is opened. One part of the DPDT switch, closed in the CW position, is wired across the modulation transformer secondary. The other section is used to open the modulator circuit. This section should be open in the CW position. Unsolder the 180 ohm cathode resistor from pin 2 of the 6AQ5's. Run a wire from pin 2 of the 6AQ5's to the switch, and run another lead to the disconnected end of the cathode resistor. Tape all exposed joints.

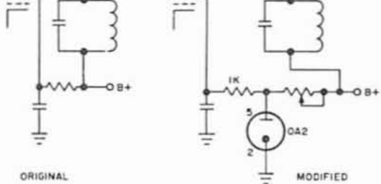


Fig. 1. Oscillator stage showing addition of VR tube.

Mount the VR tube socket and connect one end of the 15k resistor to pin 5; connect the other end of the resistor to the B+ pin on the power plug. Ground pin 2 of the VR tube socket. Replace the 6AU6 oscillator screen resistor, connected to pin 6, with a 1000 ohm, ½ watt unit. Connect one end of the resistor to pin 6 of the 6AU6 socket, and the other end to pin 5 of the VR tube socket. This will stabilize the oscillator stage, and prevent FM on Phone, and chirp on CW.

Next, mount the key jack. Wire it so that it is closed with the key out. Then unsolder pin 2 of the 6360 final stage. This is easier said than done, and may require temporary removal of other components in the area. If you are unfortunate enough to break off the pin in the process, remove the remains and replace it with a pin from another socket. Solder a 0.001 mfd disc capacitor from pin 2 to ground, and run a lead from pin 2 to the hot terminal of the key jack. Also, bypass the hot lead on the key jack to ground with a 0.001 mfd disc ceramic capacitor.

This completes the wiring. Replace all tubes; plug in an OA2, and set the adjustable resistor for about 10 ma through the OA2. With the switch in the phone position, the rig should tune up normally. In the CW position, the meter readings and the output should be somewhat higher. This is because the modulator load is removed from the power supply, causing the voltage to increase, and there is no longer a B+ drop across the modulation transformer secondary.

This scheme is applicable to nearly any small rig, and I have successfully employed cathode keying of a 5894 on 2 meters and an 829 on 6 meters. To put any other rig on CW, it is necessary only to open the final cathode circuit and install a key jack, and short the modulation transformer secondary. If the modulation transformer isn't shorted you probably will end up with a second-rate CW signal, and may be forced to purchase a new modulation transformer, modulator tubes, final, etc. Remember Lenz's Law! It isn't necessary to disable the modulator, but it does cut power consumption and is a bit

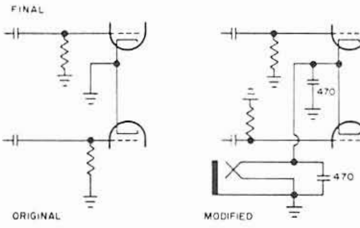


Fig. 2. Final stage indicating addition of key jack and by-pass capacitors.

more professional. This may be accomplished in many ways; opening the cathode, breaking the plate and screen circuits, opening the screen lead, etc. If your power supply has very good regulation, you may dispense with the VR tube, but it's cheap insurance against a poor signal.

This technique has been successfully applied to the Tecraft 220 transmitter and a 6360, 220 rig similar to the rig in the ARRL Handbook of a few years ago. Give it a try, get on VHF CW, and join the Great Society!

...K1OYB

220-MHz Receiver from the ARC-27

The RT-178/ARC-27 is composed of ten different subassemblies all are the plug in type.

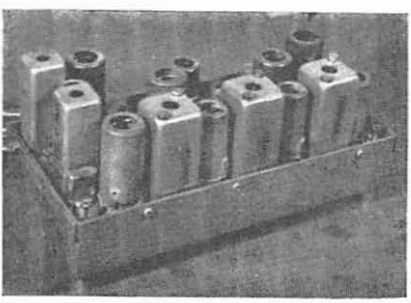
The one we are interested in is the Guard Receiver sub-assembly. Each unit is marked making identification easy. The Guard Channel Receiver is a dual conversion superheterodyne receiver with a 19.4 mc first if, and a 3.45 mc second if. The guard channel receiver also incorporates a separate detector, noise limiter and avc section has its own squelch circuit, sensitivity control and audio gain control. The receiver is crystal controlled making it useful for net and MARS operations. The original frequency of the receiver was from 238 mc to 248 mc. A few simple modifications will bring it down to 220 mc to 230 mc.

Modification of unit

Step one will require converting the filaments to 6.3 volt operation. Fig. 1 shows the original series-parallel circuit that was used with this equipment. Pins 13-10-8 of J-810 will be tied together to the 6.3 v. input. The existing wires may be used by carefully cutting the wires and rerouting it to the necessary socket pins.

Step two in the RF section will be very simple. Coils L-803, L-804 and L-802 can be brought down to 220 mc, simply by squeezing them together. They are marked on the sub-assembly. A grid dip meter should be used to bring the coils within the proper range.

Step three will require the modification of the First Injection Oscillator. It is this stage that will determine your operating frequency.



The ARC-27 guard receiver.

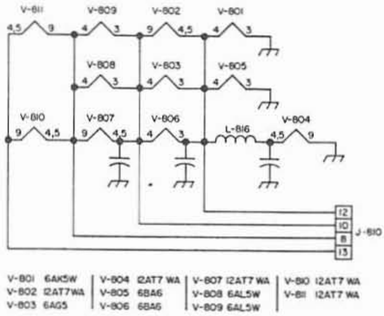


Fig. 1. Original filament circuit.

Xtal Y-801 will have to be changed to whatever frequency in the 220 mc band you wish to operate in. A 33.44 mc xtal will give you a operating frequency of 220.04 mc. The following formula will help in selecting the proper operating xtal

$$\frac{\text{operating freq. desired in mc } 19.4-}{6}$$

= input xtal freq.

You may have to add small capacitors across each coil to bring them down to the proper frequency.

Pin connections to J-810 are as follows: 5 is the sensitivity control lead. Use a 5000 ohm pot to ground. 15 is ground. 3, 4, 7, 9, and 14 are not connected to anything. 1 is −80 volts bias. 6 is +225 volts. 2 is for squelch, use a 25 k pot in parallel to .1 μf capacitor for it. 11 is audio output. The filament connections are shown in Fig. 1.

You may use whatever he mav have available in power supplies. The B+ should be 225 volts at 100 ma, and a bias voltage of −80 volts is needed. The filaments will require 6.3 volts at 3 amps.

Tuning and operation

After the RF stages and first injection oscillator have been tuned to their approximate frequency, power should then be turned on. After a smoke test the oscillator should be

checked to see that oscillation is taking place. A GDO can be used for this operation or a sensitive wave meter by close coupling to the oscillator tube (V-807). After the oscillator section is working properly a signal generator should be used to peak up the RF section. If no signal generator is available couple an antenna to J-801 and starting with C-811 cap. peak up on the noise then proceed to C-810 doing the same. Last the antenna section should be peaked with variable cap. C-803.

If speaker operation is desired an additional stage of audio will be needed which can be built into the power supply. . . . K3CES

Tunable IF Converter

This tunable I-F will work on your favorite band, six, two 432, or 1296 mhz, and even 2400 a little later.

Ten meters is used because that gives you a nice ten meter receiver for portable use, and when you're on 432, or 1296 you need at least 30 mhz to keep the image down.

Design Philosophy

This is a straightforward job with one rf stage, a mixer, and an oscillator, all tracking on a three gang capacitor from 28 to 30 mhz. See Fig. 1.

"Bipolar" (which means just the old-fashioned, regular triode type with three leads) transistors are used to keep down the cost and time of construction.

An S meter connection is shown because when you're using that high gain sharp beam up there, it's nice to know just where it does peak! And by how much, even if it's only relative.

General Notes

At this frequency, 28 to 30 mhz, almost any good vhf transistor does a good job. There is gain in the converter ahead, and gain in the i-f following, so you don't need much here. Once again, though, you do need tracking. There is a whole section on a painless method for doing this.

The main tuning (or ganged) coils are all wound identically, to help in tracking, and with the exception of the oscillator collector, all other circuits are lightly coupled to them.

L1 brings in the first i-f from the 6, 2, 432, or 1296 converter, at 28 to 30 mhz on J1. If you just happen to put almost any kind of antenna into J1 you may be surprised at the ten meter signals you hear. Just incidental.

Note that for the sake of uniformity and ease of wiring all eleven coils are returned to ground on one side. This accomplished by dc blocking capacitors from the bases, which are dc fed by resistors, and by the use of the collector dc voltage being at the baseboard level. Note that by this method most bypass capacitors are eliminated.

The copper-clad baseboard also makes it easy to ground all coils on one end. The capacitors are all the 1000 pf little ceramic jobs from Lafayette, 3/16ths of an inch

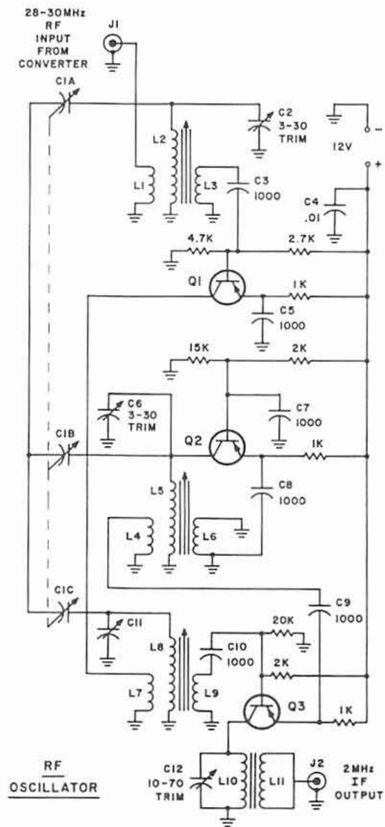


Fig. 1. 28 to 30 mhz tuneable i-f.

L1	3 turns, no. 28 DCC, close wound on ground end of L2.
L2	17 turns, no. 26 DSC, on 6/32 tapped form, 5/32 O.D., with 6/32 threaded, powdered iron core.
L3	2 turns, no. 28 DCC, as L1.
L4	2 turns, wound close on L5.
L5	As L2.
L6	3 turns close wound on L5.
L7	4 turns on L8.
L8	As L2.
L9	2 turns on L8.
L10	1 inch long iron core, 5/32 OD wound for 2 mhz, two pi.
L11	4 turns on middle of L10.

Table 1. Coil turns.

square. C1-A, B, and C was a Bud three gang with 11 pf per section. For this unit, I removed one rotor plate from each of the three sections, and also spread the 28 to 30 mhz tuning range over 80 percent of the dial.

If you have a converter or converters having other than 10 meter outputs, you can change the coils to suit. The main reason here for choice of 10 meters was the large number of "amateur band receivers" with 10 being the only band with nearly 2 mhz tuning range. This should cause converters with 10 meter outputs to be in the majority, although I have not checked with converter manufacturers on this.

All transistors just happen to be Sprague 2N1726 but you can use almost any good vhf ones, as the noise figure and gain are set elsewhere. The main deal here is to *tune* something so you can use crystal control for the uhf local oscillator where it is needed.

No critical points were found in the tune-up of this unit. For permanent use, installation in a Minibox should be used, matched to your favorite dial.

Details–RF Stage

The rf stage (refer to Fig. 1) has a tuned circuit in the base, with an untuned collector brought over to the mixer on L7. As detailed in the tracking section, the iron core is used to set the low frequency end of the tuning and the trimmer C2 sets the high frequency end. Trimmers C2, C6, and C11 also serve to spread the 2 mhz range over the dial. Battery voltage is high on the collector end of these stages which makes things a lot easier, especially for bypassing, as you will see.

Oscillator

The oscillator is a sure-fire emitter coupled job, with the collector on the high end of L5. This is done to "set" L5 as the "slowest" tuning coil of the three. The other tuning coils, L2 and L8, are then made to track with a little more trimmer capacity, matching the collector capacity of the oscillator on L5.

Oscillator output is obtained from L4 and capacity coupled to the mixer emitter. Starting from ground, wind L4 on L5 in the same direction as L5's winding, and put the emitter of Q2 on the other end. It *has* to oscillate! There is a simple law of nature that says; "If a good transistor has good coupling back from a *good* collector coil so that the base goes negative when the collector goes positive, it will generate the signals you want, upon application of good voltage."

Mixer

Note first that the mixer uses the gang capacitor section furthest away from the rf section. The rf stage has never shown any sign of nuisance feedback in this tuner so far, but it's a good precaution anyway, to keep those sections apart. No shielding was needed either, but you might just need some if you try to make the unit smaller. It's six inches deep, by five inches wide by one and three quarters high now, not including the dial.

Tuned energy from the rf collector is brought to the mixer on 4 turn coil L7, and local oscillator input is capacity fed to the mixer emitter. The output coil L10 was tuned to 2.5 mhz in this unit, although you can use a little higher or lower if you want.

As a general rule a ten to one conversion frequency is good, but you are on a trade-off here: a high ratio will make your next i-f more selective but your image possibility will increase. A low ratio will make the image disappear but then you haven't done much conversion and you may need *more* converters to get you down to the final i-f you're counting on.

Special Separate Section on Tracking

There is a very straightforward positive method for lining up coils for ganged capacitors, which will be detailed here, using the 28 to 30 mhz tunable i-f

We start here with the circuit already designed and working correctly with three

separate capacitors, one of which may be the oscillator section of the gang used.

The ganging together of the frequency versus rotation of the three section variable capacitor is not a matter to be taken lightly, however. Due to slight differences in the circuitry of the rf, mixer, and oscillator stages and their coupling, it is not enough to buy three movable iron core coil forms, wind six (example) turns on each coil, and expect them to track. The grid-dipper will not do the whole job either, although it may help some to get you started.

The first thing is to cover the range needed with the variable capacity of one of the sections of the gang, and still leave some capacity at the high end for the best Q. This residual capacity is furnished here by the parallel trimmers, which are of considerably greater capacity than the ganged sections, so that the L/C ratio actually changes very little over the range tuned.

Assuming you already have chosen the ganged capacitor suitable for the frequencies involved, which appears to be less than 10 pf per section. Check out which of the three stages takes the most variable capacity to tune the range. This will generally be the oscillator stage in this circuit. This is the one you will line up first because it is easier to stretch the frequency over the dial than it is to compress it.

Referring to **Fig. 2**, we will be concerned with connecting and disconnecting the three points shown, which will be designated hereafter by rf, mixer, and oscillator.

Now, using the completed unit, with two external capacitors temporarily tuning the rf and mixer stages, and operating into the i-f

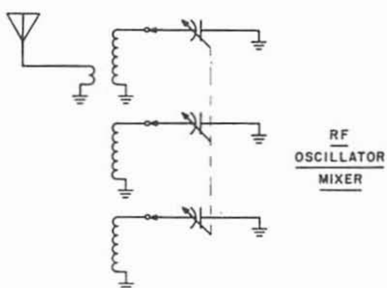


Fig. 2. Major connections for tracking.

you are going to use, such as 2 mhz, be sure everything works correctly, such as sensitivity, tuning range, absence of feedback in the rf stage, etc. Use an "S" meter or avc meter for this work. Tune the oscillator with one of the three ganged sections, and log three or five frequencies on **Table 2**. The dial must be in its permanent form. I used 28, 28.5, 29, 29.5, and 30 mhz for this purpose. The dial may also have any other scale as well on it that you may wish to set up, such as 431.9 to 434.1 for example. To make this unit you do need a signal generator, at least one of the $30 to $40 kind.

Some "quickie" manufacturers use only three points on the dial such as max., middle, and min., but that results in a $9.95 "radio." If you want to do a real job use five spot frequencies (as suggested above) for the 10 meter band as i-f for this tuner.

You can use 30 to 32 if you are afraid of rf leakage input from the 10 meter band. This whole unit should be ready to install in a Minibox with a good cover, so you should not have any trouble with i-f leakage on any frequency.

MHZ	RF	MIX	OSC
28			95
28.5			74
29			53
29.5			28
30			10

Table 2. Dial logging scales.

Now log on paper, the five frequencies chosen on a simple chart as in **Table 2**. You can see now the basic idea of this system. You have a positive, visible, and exact recording of the tracking of one of the gang sections set up. Leave the oscillator core and trimmer set from now on so that these settings do not change unless a new start is to be made. This sometimes happens!

Now take the oscillator off the gang and solder the rf on. All you should have to do now for the rf is to set the iron core to trim the low end of the range, and the parallel pad trimmer to set the high frequency end. It's not always that easy though.

Right here you may have to do some readjustment of circuit values, and possibly some hard work! The rf may not track in the middle after lining up both ends! Or vice versa.

This is the reason for those funny-looking saw cuts you may have seen in the

two outside plates of millions of ganged capacitors for over forty years! However, with the components and circuit shown in the overall schematic you will probably make out all right, although this section is intended to help you use other components, as well as helping on other frequencies.

The procedure is fairly straightforward now. Just make the rf readings coincide with those of the oscillator previously recorded by adjusting the core and the parallel trimmer. Using less core (that is, the core further out of the winding) and more trimmer you will of course "stretch" the readings on the dial. Make several runs this way and you will soon get the hang of it. And, you don't have to guess, it is logged down on paper for you.

Mixer

Now disconnect the rf, connect the mixer, and proceed as above. You should now be able to fill in the third column and be ready for the big deal.

Oscillator and Three-Gang Tracking

If the oscillator has been previously logged correctly, and the other sections fitted to those readings, on soldering all three together you should have no trouble. Don't fiddle too much with the adjustments after soldering all three connections back onto the gang, because you have no means of knowing what the curve of any one section, except the oscillator, will be.

The reason for some gang capacitors having different oscillator and rf sections, is mainly because the broadcast band has a three-to-one tuning range in frequency, whereas the oscillator for a BC band radio needs about a two-to-one tuning range.

When you are running at 28 mhz however, and the mixer is at 28 to 30 mhz, the oscillator is only some two mhz away. The tracking ranges are so close to being identical that no effect can be noticed. So in this case use a ganged capacitor in which all the sections are alike.

. . . K1CLL ■

Dual VHF Converter

The Nuvistor converter about to be described was designed for a critical vhf ham This converter has a good noise figure, ample gain and bandwidth, and is also economical to build. The dual converters reduce costs and space appreciably over two single converters.

On 220 mc the noise figure is between 3 and 4 db; over-all gain is 60 db; and the bandwidth is within 2 db of being flat from 220 to 225 mc.

On 144 mc the noise figure is between 2 and 3 db; over-all gain is 50 db and the bandwidth is ±1 db over the tuning range of 144 to 148 mc. Sensitivity in both units is .1 microvolts.

Construction

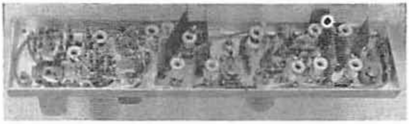
Follow the schematic and parts layout closely and you should encounter no trouble. If difficulty is found in either of the converters, a close recheck of components and wiring in each stage should uncover the fault. Usually a mere oversight by an impatient builder causes disappointment, so double check all components and examine all connections for cold joints.

The unit described was built on a homebrew chassis, but it is advisable to use a commercial chassis unless you can use a fair sized brake. The suggested commercial chassis is a Bud CU-3014-A Minibox that measures 12″ × 2½″ × 2¼″ and is made of natural aluminum. Use the "narrow sides" section as the chassis and the "wide sides" part as the cover or bottom shield.

The drilling template was made for this module showing the Bud chassis. The photos show the placement of components.

Circuit

The 220 mc converter has a 144 mc output that feeds into the cathode of the tandem 6CW4 Nuvistors of the 2 meter converter. The first Nuvistor in the 220 mc section operates as a grounded grid amplifier and the signal is fed to the cathode through a ceramic trimmer. Signal output is taken at the plate through a link and fed to L3 which is the grid coil of the second 6CW4 used as a triode mixer. You will notice that shields are provided between all 220 mc tuned circuits to prevent regeneration.

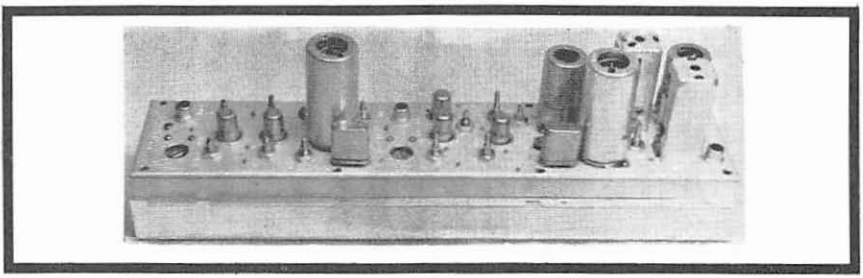


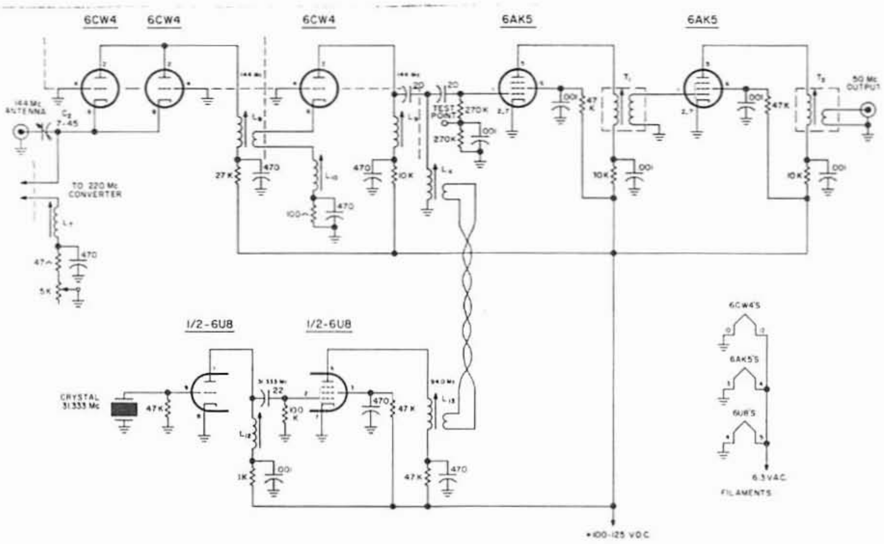
Bottom view of converter.

Needless to say, the gain of one grounded grid stage and a triode mixer is not very high. However, the signal is amplified sufficiently by the following 2 meter converter.

The local oscillator tube is a 6U8. The triode section is a crystal oscillator with its plate tuned to 25.333 mc. The pentode section of this tube is the tripler to 76 mc. The output of this section is coupled to the grid of the mixer by a 3 pf ceramic capacitor.

In the 144 mc section, we start with a link in series with the cathode coil of the tandem rf stage Nuvistors. The antenna is fed through a ceramic trimmer to the high side of





144 Mc CONVERTER

Coil Data
All coil forms—J. W. Miller No. 41A000CBI

No.	Freq.	No. Turns	Wire	Winding	Remarks
L 1	220 MC.	2½ T	#22	Spaced 1w dia.	
L 2	"	2½ T	#22	" "	3T. Link
L 3	"	3 T	#22	" "	3T. "
L 4	144 MC.	4½ T	#24	" "	
L 5	76 MC.	6 T	#24	Close wound	
L 6	25.3 MC.	20 T	#28	" "	
L 7	144 MC.	3 T	#24	Spaced 1w dia.	
L 8	"	4½ T	#24	" "	3T. Link
L 9	"	6 T	#24	" "	
L10	"	4 T	#24	" "	
L11	"	4½ T	#24	Spaced 1w dia.	3T. Link
L12	31.3 MC.	16 T	#26	Close wound	
L13	94. MC.	6 T	#24	" "	3T. Link

T1 = J. W. Miller I.F. Trans. No. 6233 Modified 45.5 MC TV Trans. (remove 3 turns from coils).
T2 = J. W. Miller Trans. No. 6231 Modified 44 MC TV Trans. (remove 3 turns from coils).

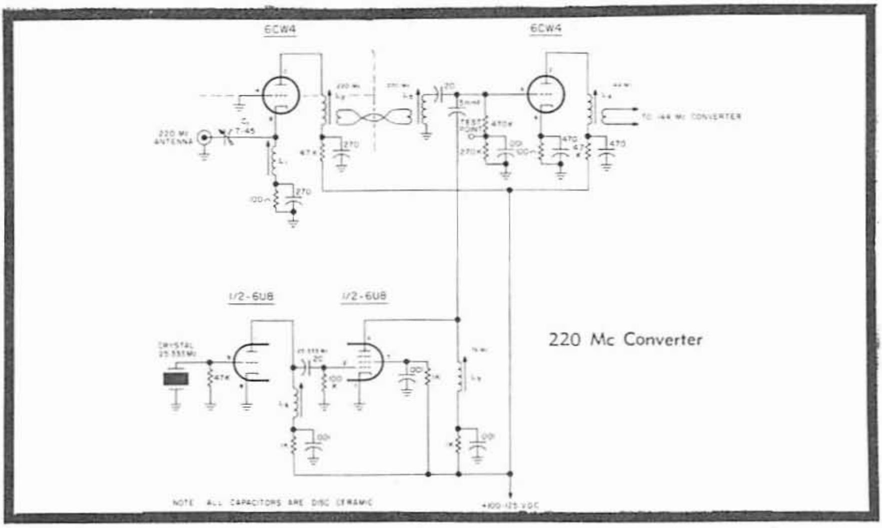
the link as shown on the schematic. The cold side of the cathode coil is by-passed with a 470 pf ceramic capacitor and is connected to a 47 ohm resistor. This resistor is connected to the 5000 ohm rf gain control. This control is not essential, but it helps prevent overloading on strong signals. Similarly, the plate circuit of this grounded grid amplifier is link coupled to the cathode of the second stage. Output of the second grounded grid amplifier is coupled to the mixer grid through a 20 pf ceramic capacitor. The mixer is a 6AK5. Its output is fed to a stage of *if* amplification at 50 mc.

The oscillator circuit is similar to the 220 mc one. Differences are the frequencies of the tuned circuits and crystal.

The *if* amplifier is also a 6AK5 and operates at relatively low plate and screen voltage. The output of this amplifier is taken off the link in T2 and connects to the output connector shown on the photo. Transformer T2 is a J. W. Miller No. 6231.

Notice that the B+ supply voltage is between 100 and 125 volts. This low supply voltage is essential in reducing over-all noise of the converters without sacrificing sensitivity. A good way to secure such voltages is a 108 volt regulator tube such as an OB2. This regulator tube can be mounted on the back of this converter chassis or on the power supply chassis.

The complete unit draws a maximum current of 20 ma at 108 volts. In the 2 meter



220 Mc Converter

position the current drawn is only 15 ma because the 220 mc section is made inoperative.

One way to cut off the 220 mc unit is to use a rotary switch and simultaneously switch the antennas and the B+ to the converters.

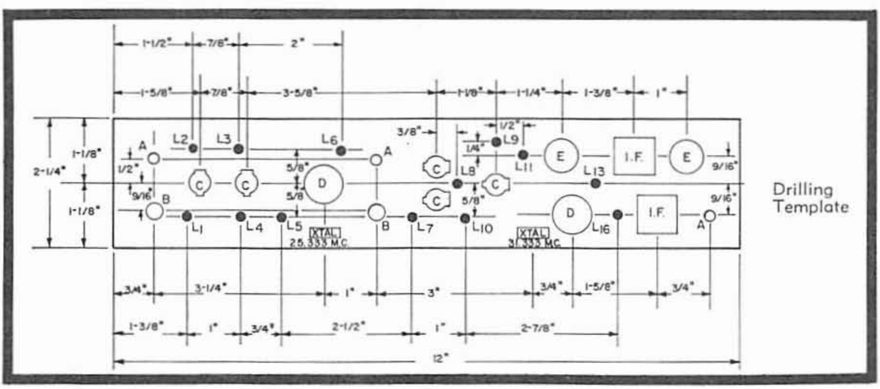
Tuning

Tuning of the converters is quite standard and follows a definite pattern. Use a dip meter to get all coils on frequency. If necessary, alter the coils by adding or eliminating a few turns or by adding a little capacitance across the coils that are too high. This won't be necessary if you follow the layout.

Be sure to short all coils near the one being dipped. Otherwise you may dip the wrong coil.

After all coils are on frequency, re-check all wiring and all component values. Connect the *if* output of the converter to a 6 meter receiver. Connect the 2 meter antenna to the 144 mc converter section and apply voltage to this section. Check the oscillator by using the grid dipper in the detector position. If the oscillator is working, the meter on the grid dipper will swing upward. Now tune in a strong signal (or use a signal from the dipper in modulated position) and peak all 2 meter coils and the *if* transformers. After this is done, tune in a weak signal and re-peak all coils for maximum gain except L7 and C2. These two are adjusted for the lowest noise and best signal quality.

After adjusting the 2 meter converter, remove the antenna from the input jack and connect an antenna to the 220 mc section. Apply power and check the activity of the oscillator. Then proceed to make adjustments as in the 144 mc section. . . . W9DUT



Drilling Template

Solid-State IF

This section deals with design methods, components, and circuits using solid-state devices leading to an i-f system that will meet the special requirements of the amateur builder who wants a reasonable-cost, selective, low-image, tunable i-f for use following converters on 6 or 2 meters, or the UHF regions above 420 MHz. This portion of the chapter describes design details of the 1.65 MHz and the 135 kHz i-f modules, using subminiature shielded coils and ICs.

Requirements

Selectivity and Freedom From Images. The easiest way for the homebrewer to get selectivity is to use a low intermediate frequency; however, this cannot be done without suffering from image trouble unless several conversions are used. An image is the unwanted signal on a frequency separated from the desired signal by twice the i-f. This is caused by the presence in a mixer collector circuit of several frequencies other than the desired one. For example, if the local oscillator is on 28.5 MHz and the desired signal is on 28 MHz, a beat note at 0.5 MHz will be produced, which is used for the i-f.

Unfortunately, a signal on 29 MHz will also produce a beat note on 0.5 MHz. This unwanted signal is called the image; you can see that it can cause considerable strain on the selectivity requirements of the rf and mixer stages in a 10 meter receiver in order to remove it. This is one of the main reasons for multiple conversion amateur receivers that use a first i-f of 1.65 or 2 MHz, which places the image some 3.3 to 4 MHz away from the desired signal. Here it can be handled by the selectivity of the two tuned circuits of the rf and mixer stages generally found in such a receiver. The requirement for reduction of the image is met in this fashion in our "ideal" i-f.

Tunable I-Fs. The use of converters with crystal-controlled local oscillators for stability reasons requires tuning somewhere else down the line. For the fellow interested only in a large, stay-put home station, this can be accomplished by using his 100 lb communications receiver, with switched inputs, etc. However, that does not meet our planned types of operations, such as battery-portable-anywhere, mobile, and emergency use, all of which are applications well suited for solid-state devices. A tunable, selective front end with rf stages, mixer, and tunable oscillator does the trick.

Practicability. The next requirement is for available components at reasonable cost. The J. W. Miller Co. has produced a line of shielded, subminiature adjustable rf coils (9050 series) which fill the bill for inductors. They have a threaded core of powdered iron in the center for trimming, an outer magnetic shielding cup which also helps the Q, and an aluminum case for electrostatic shielding (½ in. square by 9/16 in. high). They also are handy because you can easily add extra windings–for coupling with solid-state devices.

Resistors in the 1/8 and 1/10 watt range are available at most mail order houses, along with subminiature capacitors.

Active devices having high gain and low internal feedback, that do not need neutralization, are available from Motorola. The HEP 590 is one of these; it is easy to use and performs excellently.

Demodulation Characteristics. Since we are mainly concerned with AM on VHF and UHF, the demodulation is important. This is given scant treatment in many handbooks, but I find that when you're actually digging those call letters (at least!) out of the mud, you need the best possible diode circuit available. It seems, from all the tests I've made, that the diode demodulates more af when connected across the entire winding of the last tuned circuit.

AF Amplification. Next in order of importance comes a good af amplifier. There is no doubt at all in my mind on this one. The

Amperex TAA-300 is it. It has 1W output, a response of 20 Hz to 25 kHz, and an 8Ω transformerless output impedance, and sounds good. With bass and treble controls in front, it really does the job for voice communication frequencies for amateurs.

Single-Package I-F Pair. The last requirement (for now) is for a double-frequency i-f. This is just a handy phrase for the combination of the 1.65 MHz and the 135 kHz i-f in one package. You can put more gain—with greater freedom from feedback troubles—into the amplifier when the input is on one frequency and the output on another—a tried and proved method.

I-F Considerations

Let's face it, 455 kHz is not the best i-f for amateur communications receivers. Its use as an intermediate frequency dates from the early 1920s which is by now nearly 50 years ago, and was intended for the broadcast band. There was and still is a good reason for using it on the BC band: It is the only i-f that even partially suits a "cheapie" BC set. I say only partially because using a mixer on the BC band, without an rf stage in front, which many millions of BC sets do, you get images from 540 kHz up to about 690 on the dial.

Car radios, mostly working on the "me too" design theory, use 262 kHz for the i-f. The reason given: "greater selectivity." Sure, it is easier to get better selectivity with a lower i-f, but the image is worse also, so they use an rf stage. If this rf stage is properly made and tuned, it solves the problem on the BC band.

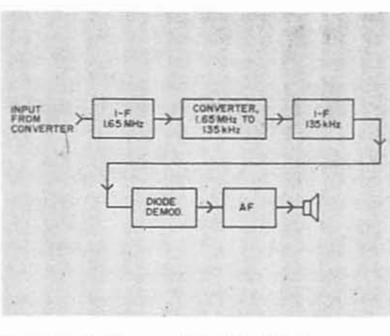


Fig. 1. Block diagram of the "ideal" i-f for amateur use.

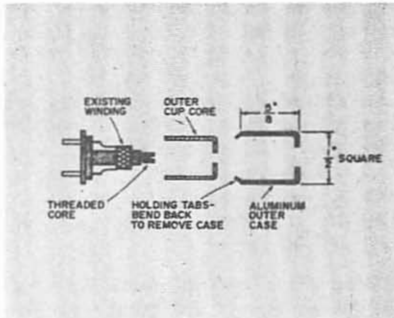


Fig. 2. Miller coils, 9050 series.

But what about amateurs? These bands begin at 160 meters, so up around 10 meters, with an i-f on 455 kHz, the image is only 910 kHz away! You can't really put an i-f in the middle of the BC band, so the next slot is up at 1.65 kHz, or near that point. This works out fine for the image problem, but now your selectivity has gone to pot.

Of course, you *can* use a Gonset-type i-f with selectivity of around 30 to 40 kHz. In fact, right here I describe a "nice little i-f" on 1.65 MHz, with just that kind of selectivity. It works fine with just a single conversion on 6 or 2 meters, but when the band opens, stay away from the low end!

So, it is probably best to devote the extra time and money required and try for the ideal i-f, which conquers images and provides excellent selectivity at the same time. There are two components which help the homebrewer reach this goal: the Miller Series 9050 subminiature coils and the Motorola HEP 590 communication IC.

Our ideal i-f will therefore look like the block diagram in **Fig. 1**. When designed, components selected, the circuit formed up, and packaged with its small battery supply, it should be a useful addition to amateur VHF, UHF, and microwave equipment.

Miller Series 9050 Coils

Here is something good, that you can really tailor to suit your needs. **Figure 2** shows the inner workings. The Bakelite base is normally supplied with two pins, but is easily drilled for four extra wires (which you need for a link-coupled base input, for example). The coil form has a neat spiral ridge inside to take the 6/32 in. threaded

core. This ridge type works better than some other types of coil holders I've used. The outer powdered iron cup generally has room between itself and the existing winding for the few extra turns needed in solid-state work. The aluminum outer case comes off easily enough after you bend back the four crimped aluminum tabs on the case that hold the coil form in place.

As you will see in the section on coil data, you can wind on 1-10 turns of link coupling and a 5-turn base coil, both on top of the existing winding, for a base input network. I used a small drill to make more holes in the Bakelite end piece to bring out the extra wires, and find the entire series adaptable from 30 MHz down to 135 kHz; and the good Q resulting from the use of these coils is particularly noticeable in the overall selectivity figure of the finished i-f. **Figure 3** shows one of them with an extra three turns installed. Until Miller comes up with something better, these are my coils.

Loaded Q vs Turns. Various sections of a communications receiver i-f have different amounts of loading, which affects the Q and energy transfer. For example, the HEP 590 input circuit works well with only a single-turn input link at 1.65 MHz, while at the same frequency a 5-turn link is required when going into the diode circuit, which is heavily loaded.

The HEP 590 output circuit, rated at 100 kΩ ac impedance, needs only 2 turns for maximum transfer of energy into a 50Ω cable or link to the next stage. Naturally, a lot depends on what impedance you're looking into, or out of, and how it is treated. The HEP 590 input circuit, rated at 1.8 kΩ ac impedance—if loaded directly onto the inductor—will swamp the Q way down.

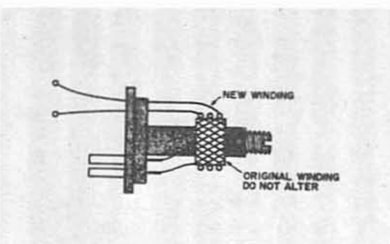


Fig. 3. Two holes at the bottom of the coil permit the two additional leads to be brought out with the original windings.

Looking at **Fig. 1**, you can see what has to be done for this type of i-f. A winding of the correct number of turns to suit the impedance of the IC is installed over the existing tuned circuit, which is resonated at 1.65 MHz. A cable input link of only a single turn is also wound over the same resonant circuit. Don't forget that the presence of the powdered iron both inside and outside aids this coupling. When the inductor is heavily loaded and the Q is lowered, the number of turns required to effect a transfer of energy may be as much as five times greater. This can also be seen in the coil table in **Figs. 4** and **7**. The base input is very easy to match by this method of varying the number of turns, as in **Fig. 4** (L4) and in **Fig. 7** (L3).

When using link coupling, which is very desirable at times *with modulator type units*, be careful not to couple too tightly (by the use of too many turns). This will show up as excessive detuning of one tuned circuit by the one link-coupled to it. It may also cause broad tuning. For maximum selectivity and proper handling, use slightly *less* than the coupling showing maximum energy transfer. Remember, *gain* is cheap, *selectivity* is not.

The 1.65 MHz and the 135 kHz modules will be described first , and the converter and avc detail next.

The 1.65 MHz I-F Module

This unit is what you could call a "nice little i-f." Following a 6 meter front end, it has *plenty* of gain, and selectivity of 30 to 40 kHz. It is also very easy to tune on 6 or 2 meters.

The schematic is shown in **Fig. 4**. Each of the seven windings, L1 through L7, has been the subject of considerable work and testing here. for selectivity and general handling properties. The tunable i-f or VHF converter shown at the left is not taken up here. It does use one of the Miller series 9050 coils, though, as shown for L1, with but one turn added on to it for feeding the 1.65 MHz i-f energy over to the i-f module being described. Inductor L2 is installed on top of the existing winding of the 9054 coil. Also low in turns is L3, with only one turn being needed at 1.65 MHz, due to the high Q of the 9054 design. Coil L4 is another 9054, which has a third winding going to the base

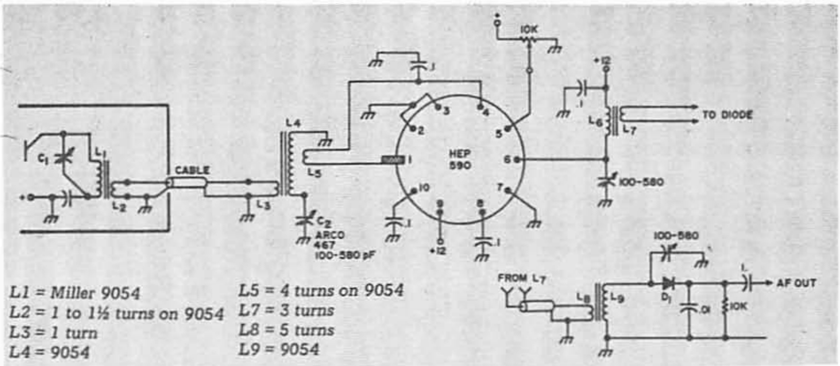


Fig. 4. Coil interconnection and winding data. At left is VHF converter (Part II). Test diode demodulator schematic is shown at lower right.

of Q1 in the HEP 590 IC. The input of the HEP 590 is rated at 1.8 kΩ.

The input tuning of C2 is very sharp due to the correct amount of coupling to L4 which has a high loaded Q.

Inside the IC there are three transistors and a diode. The two transistors that do the amplifying are arranged as in **Fig. 5**, in a grounded-emitter, grounded-base pair, which is a high-gain configuration with no detectable internal feedback. The third transistor is connected as an avc unit, and the diode is used for temperature control.

Another Miller 9054 is connected to the output circuit on pin 6 and tuned by an Arco 467 mica compression trimmer of 100 to 580 pF capacitance. You can also get the needed capacitance by using fixed dipped micas and trimming up to 1.65 MHz with the threaded-core tuning slug. If you do it this way, be sure to adjust the fixed capacitors so that most of the slug remains *inside* the winding for best coupling and Q.

A 3-turn link winding is added to L6, which goes to an output connection. For tuning up, I used L8, L9, and a diode. When used with a tunable front end on 6 or 2 meters, this makes that "nice little i-f." Follow it with a good af and try it. You'll be surprised. It does not have ideal selectivity, but a 6 meter front end is wonderfully easy to tune with it!

Pin 5 of the HEP 590 can be used for a temporary manual gain control with just a pot as in **Fig. 6**. Nothing else is needed.

135 kHz I-F Module

My bypassing of the converter module to describe the 135 kHz i-f may seem abrupt,

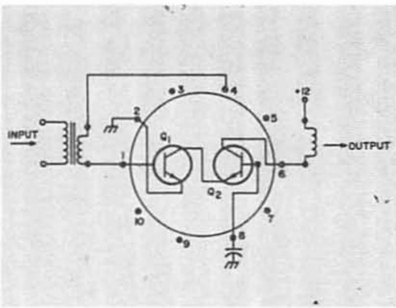


Fig. 5. Internal details, HEP 590, Motorola.

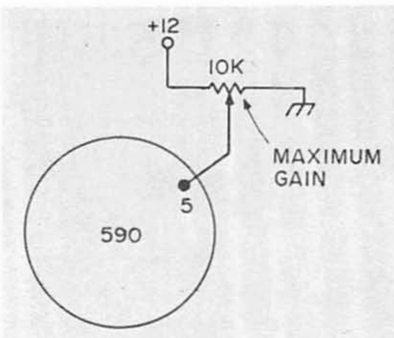


Fig. 6.

but the work involved with the i-f coils and the IC units makes the continuity better this way.

Figure 7 shows the schematic of this module using the Miller subminiature 9060 coils (with added windings) and the Motorola HEP 590 IC. The circuit is quite similar to the 1.65 MHz version except for the output.

The Miller 9060 tunes to 135 kHz with an Arco 100 to 580 pF trimmer, but here again you can make up the capacitor with the small dipped mica ones to bring the 9060 near resonance and trim to the exact frequency with the internal threaded slug.

The input cable from the converter module goes to L1, a 5-turn winding installed over the existing winding of the 9060. I use 32 AWG double cotton-covered for this and put small tabs on the input wires of coil L1 for identification. You can also use different colored wire if you have it on hand.

The HEP 590 was described in the first i-f section. It is treated identically, except that pin 5 is left grounded, keeping the gain full on, which is best for avc action because this is the unit that drives the avc diode and needs full gain.

The output coil is another 9060, with the diode connected to the *high* end. Some circuits call for tapping down the diode on the coil, but we have never found any connection as good as that shown in Fig. 7 for high quality af output. Only two tuned circuits are shown here but there is a third in the converter module; the total selectivity is thus as sharp as you may want to use, because you can still recognize your friends' voices on the air.

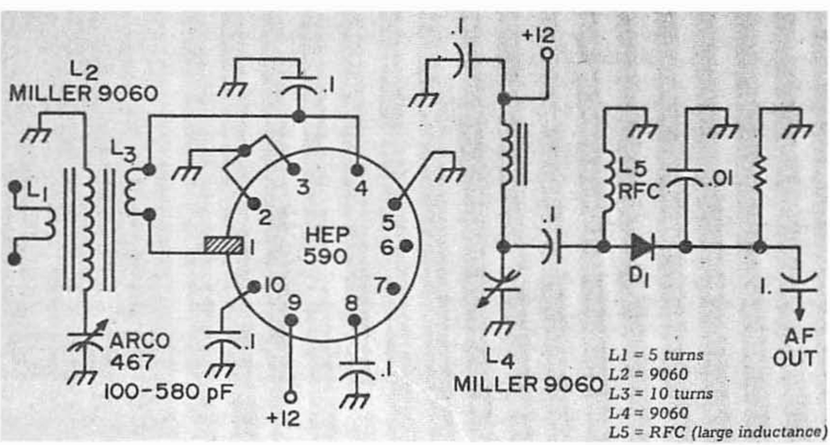
Breadboarding the complete IC system.

Our next consideration is the design method and working breadboard model of the 1.65 MHz to 135 kHz converter module, a 135 kHz i-f filter which really cuts the mustard, an avc module for use with the Motorola HEP 590 IC i-f amplifier, and the results when using the whole i-f system. If you like plenty of lows when listening on the bands, this is the unit for you; the bandwidth is between 3 and 4 kHz, which is cutting it pretty close for good voice quality. Of course, when the going gets real tough, you don't care about quality, but you do care plenty about understanding what your contact says. That's when a narrow bandwidth really helps.

Overall System

Figure 8 shows the block diagram of the complete triple-conversion portable receiver. Previous sections have described detailed construction of various portions of this system. This section is concerned with the 1.65 MHz

Fig. 7. 135 kHz i-f, with HEP 590 and Miller coils.



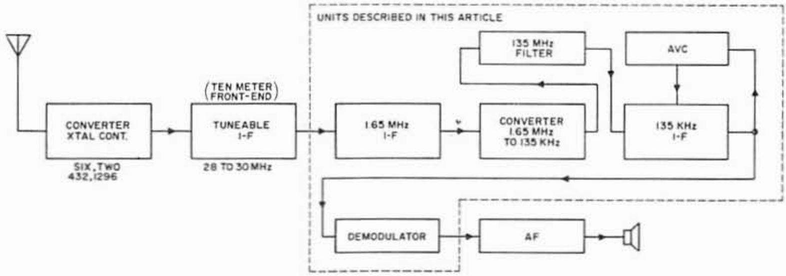


Fig. 8 Block diagram, ideal i-f system.

to 135 kHz converter, the avc module, and the 135 kHz filter.

Instead of the first crystal-controlled converter followed by the tunable 10 meter front end, you can use a tunable 6 meter job if you wish, resulting in a double-conversion receiver. You can even use it that way on 2m, but tuning gets pretty touchy then. The crystal oscillator in the VHF–UHF converters relegates the tuning business further down the line to the 28 MHz region, where it can be done in a reasonable fashion.

Once the i-f system is packaged and installed in a little carrying rack along with the desired converter and companion solid-state transmitter, it should make an extremely interesting and useful addition to portable amateur equipment –and at reasonable cost for the homebrewer.

Mixer

In the past we have described several 1.65 MHz mixers, but this is the first using ready-made coils that you can buy on the market; that is, these are the Miller series, described in detail in the first part of this chapter. Of course, you do have to add an extra winding or so, but the coil form, adjustable center threaded core, tuned winding, outer powdered-iron core, and the aluminum case are all there.

On the subject of mixers, be sure to read the "trouble" section, where it shows what happens when you put a high Q coil in the collector circuit of a lively mixer and leave the emitter only partly tied to ground. In this condition, you're in grave danger of very strong oscillation on 1.65 MHz (if that is the frequency of the output circuit).

Various types of oscillator injections were tried, and the one shown in Fig. 9 is the result. It uses straight link coupling from the oscillator inductor to the mixer base coil, and has the nice feature that the amount of coupling is easily adjusted for the best effect. This is useful because if you undercouple you lose gain, and if you overcouple you can get frequency "pulling"; unwanted harmonic power rises also. You will notice several windings of only 3 turns or so, which is a small number at an intermediate frequency. This is possible because of the powdered-iron cup core used, which increases the magnetic coupling and the Q of the coils. Figure 9 shows the mixer circuit using the Miller coils.

Here's how it works: Signal energy from the 1.65 MHz i-f module comes in on L1 and is transferred selectively to L2, and from there to L3, which is matched to the base input of Q1. Oscillator energy at 1.785 MHz is supplied also to Q1 via L4, and the two

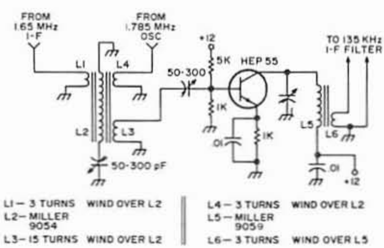
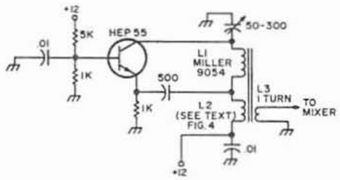


Fig. 9 1.65 MHz to 135 kHz converter mixer detail.



L1 = Miller, 9054
L2 = Add-on winding, see text and Fig. 4.
L3 = 1 turn.

Fig.10. Converter, local oscillator, 1.785 MHz.

signals are mixed, or beat, in Q1, to furnish a collector output on 135 kHz.

The collector circuit is tuned to 135 kHz with a Miller 9054 inductor and a mica compression trimmer of 100 to 500 pF. A link of 3 turns is wound on top of the 9054 winding to couple energy to the filter. The base and the emitter are treated in the usual fashion for dc bias, with the emitter heavily bypassed to ground, which effectively eliminates self-oscillation.

1.785 MHz Oscillator

The basic circuit of this oscillator has not been changed from that described earlier, but this time it uses coils that are readily available. The Miller 9054 unit works fine with the addition of only 6 turns of wire to create an emitter feedback tap, as in Fig. 10, and a pickup link to transfer the needed energy over to the mixer.

How to do it. Remove the aluminum can from the Miller 9054 coil by bending back the little tabs holding it in place, and make sure that the outer cup core stays in place inside the can. Figure 11 shows the oscillator winding details. You *must* get the direction of the feedback winding right or it will not oscillate. Find the direction of the winding making up the original 9054 by looking for the wire coming off the outside and going to one of the two terminals. Then wind on an additional 6 turns in the same direction without changing L1. Figure 11 should show you exactly how this is done. Join the start of L2 to the outer end of L1 at the pin. This point will now become the emitter tap connection as shown in Fig.10. Bring out the finish of L2 and connect it to the B+, bypassed by C3.

Wind on one turn for L3 on top of L1 and L2 (a little coil dope helps hold them on). We use coil wax for easy changing, due to my experimental work, but coil dope cement is all right once the circuit is working correctly.

And that's it. You can clip on an rf detector as shown in Fig.12 for a check on power and frequency. Use an absorption wavemeter or a dipper in the diode position for this test to find the fundamental. Then you can trim up to an exact spot with your receiver.

Use the least amount of power needed to drive the mixer. This will cut down on 1.785 MHz harmonics and "birdies" from getting into the front end of your complete receiver. The value of shielding cannot be overemphasized. Keep any and all rf out of the battery leads, and keep closed-in cable connections to your beam antenna lead.

The best things for elimination of birdies can thus be listed as follows:

- Reduce oscillator power.
- Carefully shield the oscillator and mixer, and filter the battery leads.
- Shield the front end from nearby pickup.

Note that the birdies are 1.785 MHz harmonics and are not i-f leakage, which is pickup of signals on 1.65 MHz. I-f leakage is much more troublesome up front in a receiver, such as on 10 meters, between the 28 MHz tuner and the VHF or UHF converter.

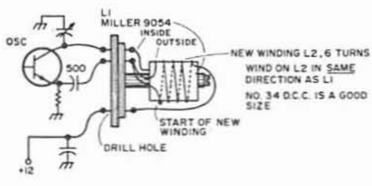


Fig.11. Oscillator coil detail, 1.785 MHz.

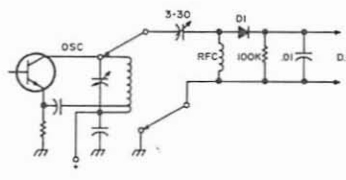
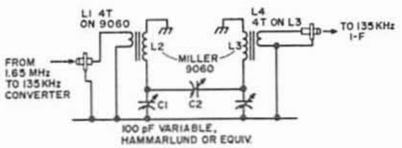


Fig.12. Diode rf tester.



L1 = 4 turns wound on 9060
L2 = Miller 9060
L3 = Miller 9060
L4 = 4 turns wound on L3

Fig.13. 135 kHz filter.

Plenty of VHF converter output swamps such pickup, and good cabling and front-end shielding help to minimize that type of leakage.

Do-It-Yourself-Filter

As mentioned in the diode section (later) on demodulation, the more tests we make, the more we like the diode across the entire inductance; however, the selectivity suffers a little as a result. Looking for that sometimes-elusive 3-4 kHz bandwidth, we checked the operation of a filter. I'm not always particularly impressed with the way some designers use filters. They have a tendency to use just one filter and a lot of amplification along with it, and it doesn't always sound right in operation. So this one was started with plenty of reservations; but after several days of trial and retrial it turned out to be a real goodie. That is, when used in *conjunction with* three other other tuned circuits as well as on 135 kHz. Figure 13 shows the circuit which is a simple "top-coupled" two section job. There are several methods of coupling filter sections, such as link, mutual induction, and magnetic (wound on the same core but spaced). The one shown worked out best and is fairly easy to adjust, with one caution: With a given number of link-coupling turns, maximum transfer of energy may be 10 dB or so down, even with the best adjustment of C. It is a *combination* of the proper number of link-coupling turns (L1 and L4) that produce the happy result of low transfer loss and minimum usable bandwidth.

Theoretical design of filters is a very complicated affair mathematically. Just make it as shown in Fig. 13 and it will do fine. The entire i-f is already too sharp for a hi-fi AM tuner right now, and does cut the highs noticeably. You could add another filter with possibly another HEP 590 in between but then you might not be able to use it on AM voice.

This filter, in combination with the three other tuned circuits, has been put to use for several days, changing back and forth between 10 meters, the BC band, and the signal generator. This BC band can be quite informative when used with the signal generator and the amateur bands, because you do want to be able to understand the other party to a QSO even though you're looking for a lot of selectivity. When you have 8 to 10 kHz of flat-top bandwidth, you can do pretty well on the clear channel stations. This clear channel business concerns the FCC's frequency allocations and does not take into account the ideas of Canadians, Mexicans, and Cuban broadcasters, to mention a few. The best thing to do for this test is to check your location and the frequency allocations for a strong local and a not-too-distant next-channel station in the daytime. Incidentally, look out for those BC stations that use *over* 100% modulation.

When we checked on the signal generator, using the filter, and measured ±1.5-2 kHz for about 6 dB down, we've got a good communications set bandwidth. This shows up on the BC band with definite cutting of highs. Bear in mind we are not talking about a $600 set, which can afford bandwidth switching. This is just a good homebrew filter job that can be put together on your bench for a few dollars, plus more than just a few days.

For best results this unit should be installed in a Minibox, although it also handled well on a copper-clad 5 x 8 in. baseboard. You can also switch the filter in and out, with suitable care, as in Fig. 14.

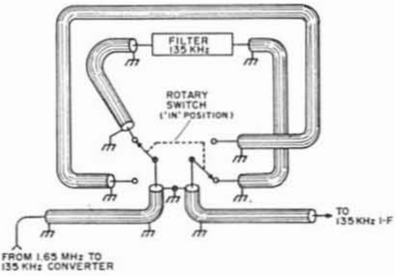


Fig. 14. Bandwidth switch, 135 kHz tuner.

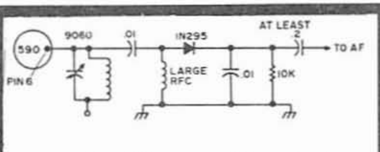


Fig. 15. Best demodulator circuit.

Demodulator

We spent lots of time on the demodulator, most of it in conjunction with the bandwidth determination and the filter operation, as these all go together to produce the desired results. The avc system is also tailored to fit in with the demodulator.

Believe it or not, those of you who have yet to experience hours-long DX work on VHF or UHF, the "rushing" sound of the noise made by the receiver itself can be important. It should not be a shrill hiss; it should be a "businesslike" roar, of low tone, and the slightest hint of a signal, even the smallest fraction of a microvolt, should be detectable (by ear as well as on the S-meter). You can see the logic of this when you consider the bandwidth of noise itself. With this i-f system, demodulator, filter, and af, the above is what happens. Of course, you *do* need a low noise front end also and this need automatically becomes greater as you go from 6 to 2 meters, and on up.

Figure 15 shows the best circuit found for the important function of demodulation. With this one you *will* hear that signal, the af quality will be good, and your chances of enjoying those QSOs will be best.

It should be followed by a good tone control circuit and a good af amplifier such as the Amperex TAA-300, and a good speaker. You need some lows in there to punch through the QRN.

AVC Circuit

The use of the Motorola HEP 590 as an i-f amplifier results in considerable advantage, but it also changes the avc requirements, as you will see.

Referring to Fig. 16, pin 5 of the HEP 590 is the avc connection. When pin 5 has 6V or more of positive voltage, the current of Q1 is shunted through Q3, and taken away from Q2 which reduces the gain of the entire circuit. The big advantage with the IC is that avc can be applied to the last i-f stage, which is also the same stage that is driving the avc system. With a single transistor amplifier stage, this is not normally recommended, but with the HEP 590 it works fine. Another advantage is that you now have places to install an S-meter that reads forward. This is across the avc amplifier collector resistor (Fig. 16).

Figure 16 shows the final circuit which holds the rectified dc voltage down to less than 1V—even on those Texas kilowatts. A *PNP* transistor is used in an "upside-down" fashion as the avc amplifier. An advantage of the use of an avc amplifier is that very little of the i-f energy is needed to operate the avc system, and no noise at all is contributed by it to the signals.

When testing this out on a signal, with the avc module removed from the IC, the effect of connecting or disconnecting C1 from the i-f was hardly noticeable.

How it works. Referring to Fig.16, a small portion of the 135 kHz i-f energy is taken off the IC output inductor through the trimmer C1 and fed to diode D1. Capacitor C1 is a very handy place to adjust the amount of avc action. With a meter checking the dc output of the demodulator, backing off on C1 drops the avc output and raises the diode voltage to a point where D2 overloads. Increasing C1 raises the avc output and drops the voltage on D2 to less than 1V on the loudest signals. You can set this to suit your own fancy.

The i-f voltage on D1 causes negative voltage to appear at the base of Q1 (a PNP connected upside-down), which then conducts, driving the collector towards the +12V. This positive output is filtered by C3 and applied to pin 5 of the IC amplifier where, as soon as the 6V level is reached, it

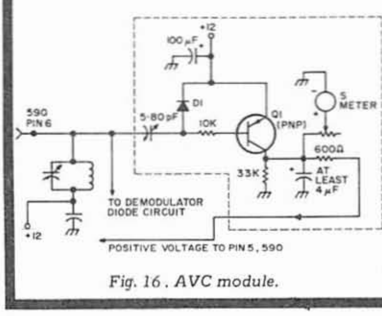


Fig. 16. AVC module.

begins to cut down on the gain of the HEP 590. On a very strong signal, like a W5 on 10m with an ordinary band opening, this voltage may reach plus 7½V or so. It is perfectly possible to apply the avc voltage to the HEP 590 used in the 1.65 MHz i-f also, but this is taken up later, when the whole system gets packaged into its 99% "ideal" form, in Miniboxes.

Don't be worried about the upside-down PNP. This is a usual practice nowadays. Just "stand" on the +12V bus as though it were the ground, along with the emitter, and look at the ground as though it were the battery voltage for the collector. It works!

Complete System Tuneup and Operation

This is where you can really take it on the chin as you first turn the entire rig on, with unbelievable sounds coming from the speaker. Too much gain, birdies, low-frequency burble, high-frequency oscillations, broad-tuning squeals, and assorted tunable hisses are some of the things that can assault your ears when you connect an antenna, the 10 meter front end, the first i-f, the second converter, the filter, the second i-f, demodulator, af, and speaker–and switch on the battery. (The overall circuit, incidentally, is shown in Fig. 17.)

Table 1. Coils for "ideal" i-f system.

L	Number of turns or coil type	Notes
1	1 turn	Wind on 9054
2	Miller 9054	
3	4 turns	Wind on 9054, L2
4	9054	
5	3 turns	Wind on 9054, L4
6	3 turns	Wind on L7
7	9054	
8	3 turns	Wind on L7
9	15 turns	Wind on L7
10	Miller 9059	
11	3 turns	Wind on L10
12	9054	
13	6 turns	Add on to L12 (text)
14	1 turn	
15	4 turns	Wind on L16
16	Miller 9060	
17	Miller 9060	
18	4 turns	Wind on L17
19	5 turns	Wind on L20
20	9060	
21	10 turns	Wind on L20
22	9060	
RFC	Large	Self-resonant below 100 kHz

In commercial receivers you often see items such as a 300Ω resistor in series with the mixer collector, going to the i-f output transformer, or a large bypass capacitor to ground on a mixer emitter which at the same time is supposed to receive oscillator inject-

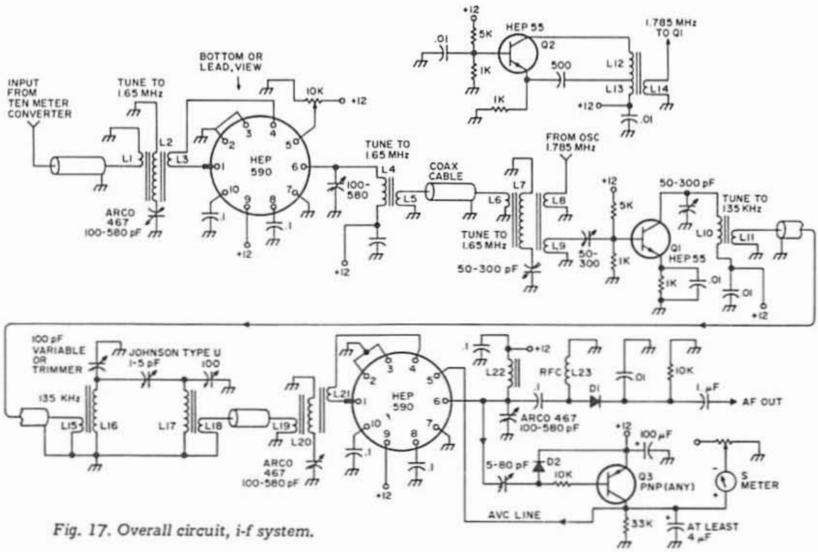


Fig. 17. Overall circuit, i-f system.

ion. It does apparently, but only in spite of all known electrical laws! Such fixes can be considered legitimate in that they do allow the system to operate in a satisfactory manner.

Trouble Department

You might think a mixer would be the last item in a receiver to develop real trouble. After all, it is supposed to just sit there, and is not supposed to oscillate or amplify, although some of them do have quite a lot of conversion gain. What would you say about one that oscillated about 5V worth all by itself?. . .cut off the local-oscillator drive, remove any input and still it oscillates?

Figure 18 shows the circuit that did it. DO NOT USE IT! It so happens that to make an oscillator, you ground the base, put a tuned circuit in the collector, and lift the *emitter* off *ground*. See the resemblance? In that mixer the emitter can be considered to be grounded through C2, but it is *not* a *positive* ground. Also, the base is not supposed to be grounded, but there is a very short low-impedance path through C1 and L1, or the base input tap on the rf collector coil. Well, to cut the sad story short, it *did* oscillate. . .like mad! So the circuit shown in the mixer section, Fig. 9, was installed and so far *this* mixer has not oscillated since then. Period.

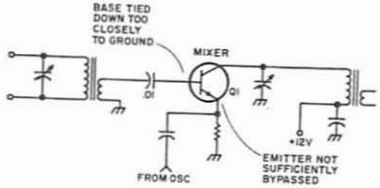


Fig. 18. Trouble-prone mixer circuit. (Do not use.)

Results

The finished system was hooked up as shown in the block diagram, Fig. 8, with my old faithful 100 ft wire attached to the 10 meter front end.

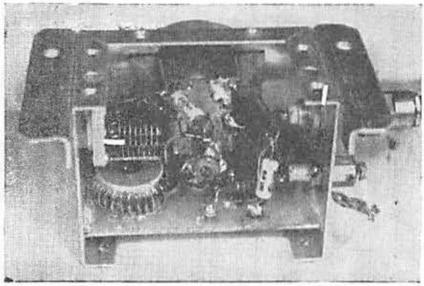
The use of a good dial in the tunable i-f on 10 meters is imperative for an i-f of this bandwidth. The Miller MD-4 two-speed dial does a good job in that unit.

If you want to improve it even further, install a bandwidth switch in front of the filter to cut it in or out Figure 14 shows this unit. There is an increase in bandwidth when you cut the filter out. This is good for non-DX contacts and locals. For real DX, switch to the 3–4 kHz bandwidth position, which cuts it down to the minimum noise condition.

. . .K1CLL ■

VFO for 6 or 2

Like to build a small, simple, inexpensive, stable VFO for VHF or UHF use? The basic VFO described here drifts less than 80 Hz total in three hours, yet can be built very easily. The VHF model of the VFO is shown in **Fig. 1.** It can be used on six or two meters as it furnishes 24 or 25 MHz output with an oscillator in the 8 MHz range. The high frequency model shown in **Fig. 2** is designed for use with an SSB mixer and operates at 5-6 MHz. Two methods of tuning are shown. One uses a conventional air variable capacitor. The other uses a piston trimmer capacitor which offers very small size, excellent stability and easy tuning.



Inside of the portable VFO for six or two showing the construction.

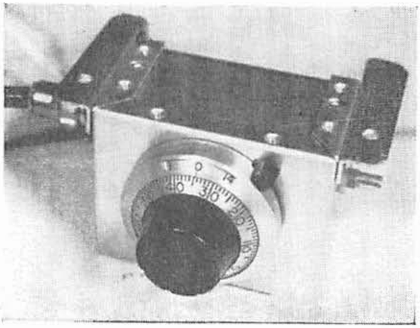
Circuit description

The circuits of the two models are similar. Each starts with a modified high capacitance Clapp oscillator using a toroidal coil. The coil (L1 in each case) is wound on a small toroidal form and features a very high Q (around 250) on a Boonton Q Meter. The coil and the capacitors C1 through C6 form a resonant frequency at the VFO frequency. Series tuning is done with C1 through C4. C1 is used to set the basic frequency range, C2 is for temperature compensation, C3 is the calibration trimmer and C4 is the tuning capacitor. The range of C4 is determinded by the frequency coverage desired. On two meters, 10 pF is more than adequate, but this value only gives 1.8 MHz range on six. For the 5-6 MHz range, 70 pF of range is needed to cover 1 MHz. This means that the capacitor must have a maximum value of about 75 pF.

C5 and C6 form a capacitive divider for feedback voltage. Using the same value for both capacitors insures that the feedback circuit is balanced. Changing the supply voltage affects the VFO frequency very little so a voltage regulator is not required.

Output is coupled from the emitter of the oscillator with a 100 pF capacitor. Don't use more than 100 pF because of loading effects on the oscillator circuit. The lowest value that can be used is best.

The second stage of the circuit (Q2 and its circuitry) is used as an untuned buffer at the same frequency as the oscillator in the 5-6 MHz VFO. Its output is low impedance from the emitter. In the two or six meter model, the second stage is a tripler to about 24 MHz with an rf choke in a broadband collector



Front view of the six or two meter VFO using a piston tuning capacitor as shown in Fig. 3.

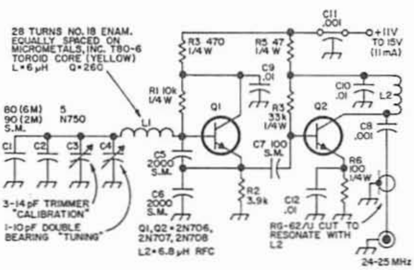


Fig. 1. Six or two meter transistor VFO with output on 24-25 MHz. The oscillator operates on 8-8.3 MHz.

circuit. The output is high impedance and used to drive a vacuum tube grid at this station.

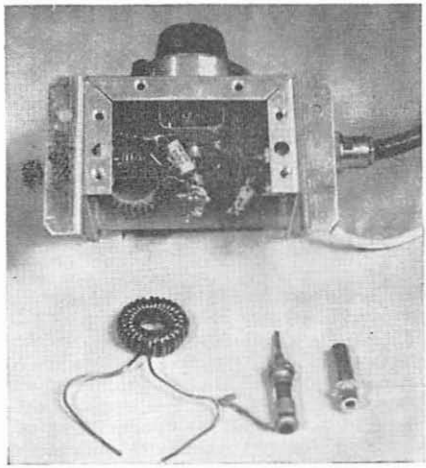
The circuits in Figs. 1 and 2 both perform well. We've built the two meter and 5-6 MHz versions, but it should be easy to cover six with the two meter model by reducing the value of C1.

Construction details

The VFO's shown in the photos are the results of using the same basic ciruit but using different construction techniques. The toroidal coil L1 used in both models is constructed by winding heavy gauge wire on the proper toroidal core. A good stable core with high permeability is a neccesity. Several manufacturers make suitable cores. We used a Micrometals core, which can be obtained from Micrometals, 72 E. Montecito Ave., Sierra Madre, California, or from one of their representatives. They have a minimum charge of $10 per order, but for $10, I was able to obtain a life-time supply of cores as each is very inexpensive when you buy a large number. I'd recommend that you write for their catalog and then order the cores.

If you'd rather not buy so many cores, Ami-Tron Associates, 12033 Otsego St., North Hollywood, California, will sell you an individual core for only 60¢ postpaid. You can also make up the proper coil inductance with the Ami-Tron RF Toroid Balun Kit available at many radio distributors.

After winding the wire on the core, the coil should be given a heavy coat of Hi-Q varnish or dope to prevent the wire from moving. All the capacitors in the circuit must be of good quality. A temperature-compensating capacitor is used to correct the minor drift in the circuit. All frequency-determining components must be securely mounted to prevent change in frequency due to movement of parts and wires.



Parts for the portable VFO. This VFO was made for two, but can be used on six with minor changes, or on 5-6 MHz.

Mobile VFO for two or six

The two meter VFO shown in the photos was built in a small package for mobile use. This VFO used a piston capacitor. Oscillator parts, transistors and the toroidal coil were mounted on a section of insulated board and cemented to the box with epoxy. This unit was built in a hurry for use during a trip so a few short cuts were taken. The box used was an LMB tight fit chassis box with self-tapping screws to fasten down the edges, but a sturdier box would be better. The tuning capacitor (C4, 1-10 pF) used in the two meter model came from surplus. This capacitor was mounted on a U-shaped bracket with its shaft moved by a stationary bushing (see Fig. 3). A hollow shaft was drilled out for a very tight fit over the bushing. This allows the capacitor to be turned with practically no backlash. A turn-count dial was fastened to the front of

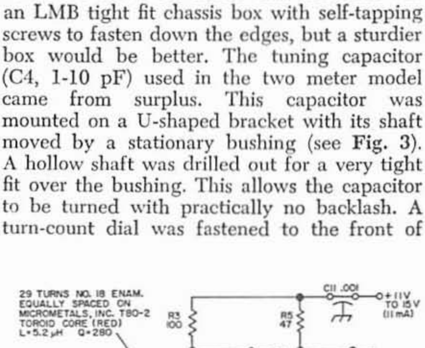
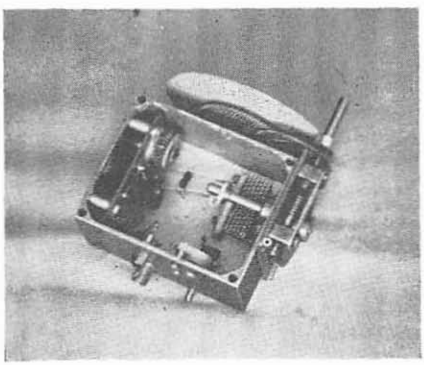


Fig. 2. Transistor VFO for 5-6 MHz for SSB mixing service.

the VFO box and a calibration chart was made. With 22 turns, the capacitor has about 9 pF of travel, or from 8.0-8.3 MHz on the VFO. This resulted in a very stable VFO which could be tuned to zero beat while driving.

5-6 MHz VFO

This VFO used different construction than the two meter one. The VFO parts were mounted on the insulated board as described before, but the box and tuning mechanism use a different technique. The box used was made from heavy cast aluminum found in a surplus store, with a cover fabricated from 1/8 inch aluminum. A sturdy double bearing capacitor was used for tuning. A gear drive and dial assembly from an ARC 5 transmitter was adapted to the VFO. This gear assembly gives plenty of bandspread with smooth tuning and very little backlash, though the mechanical work was a bit tedious. 48 turns are required



Construction of VFO using parts from a command set transmitter dial.

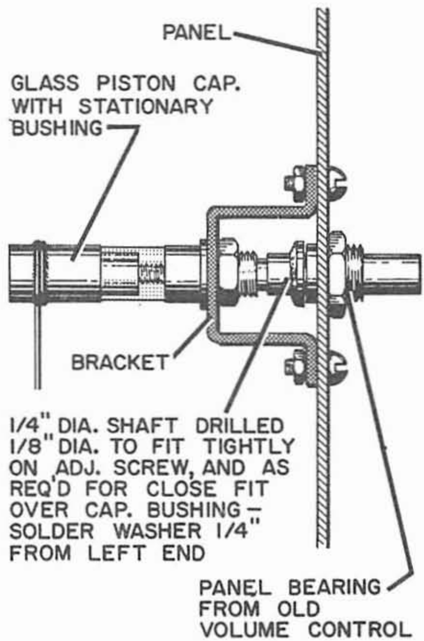


Fig. 3. Mounting the piston trimmer used in the portable VFO. A regular tuning capacitor can also be used.

to cover the 1 MHz range from 5-6 MHz, which is very nice for SSB tuning. A round plastic dial was cut out and installed in place of the original dial.

Both VFO's have given very good results. The two meter model in particular has provided much better stability reports than commercial VFO's.

. . . K6RIL

Permeability Tuned VFO

This oscillator uses basically a Clapp circuit. The capacitive swamping is not as heavy as usually used, but this seems to have no bad effects in this case.

The circuit as shown has been tested with various inductances and capacitances and oscillates up to 25 mc. It would probably work above that frequency.

The transistors are 2N708's. These are NPN silicon high frequency transistors operated in this circuit at very small fractions of their ratings. At least one manufacturer sells these at less than $1.50 each. Other similar transistors will undoubtedly work in the circuit, but the 2N708's are about as inexpensive as any readily available which have good high frequency characteristics.

The oscillator is followed by an emitter follower. This is followed by a class A amplifier which is followed by another emitter follower for low impedance output to a cable. The VFO shown will produce a useful voltage across a 50 ohm load. A 75 ohm load gives a little more voltage still.

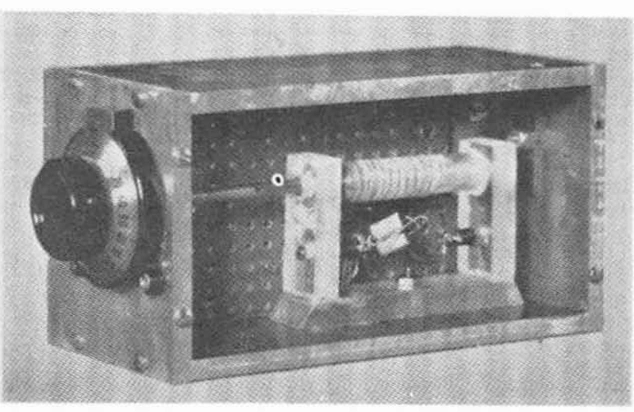
It is not, of course, necessary to use the permeability tuning shown with this circuit, but the series capacitance should be kept fairly high for oscillation to start readily if a variable capacitor and fixed inductor are used.

Mechanical details

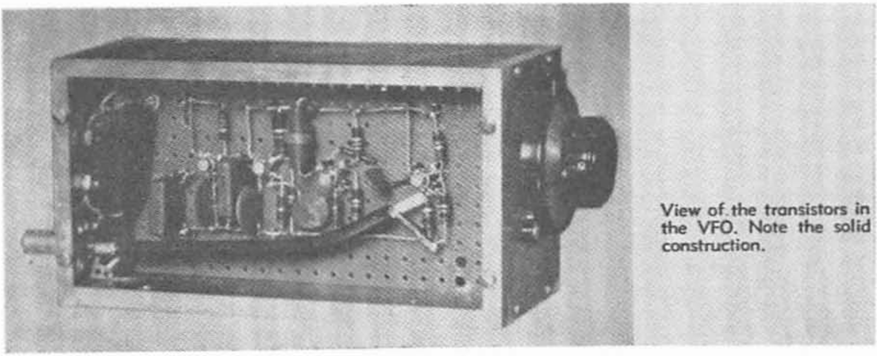
The circuit is built on Vector board using flea clips. Standard components were employed throughout, and no difficulty was encountered due to any unwanted couplings. The transistors are soldered in (after mounting *all* the other components to the flea clips). The silicon transistors are very tolerant of heat, but the iron should not be applied to the leads for more than about five seconds. That will be more than enough. No heat sinks were used.

The box used in this case to house the unit was made from ¼" aluminum, top, bottom, front and back, with ⅛" aluminum sides. This is undoubtedly overdoing the rigidity bit, but it was available. A sufficiently rigid enclosure can be made from ⅛" aluminum (rack-panel type) with angle stock at the corners (do it yourself stock available in hardware store or from Sears, Roebuck).

Use batteries for the power supply. The VFO frequency varies with voltage and even with a well regulated laboratory type AC supply some FM could be detected as a rough note at the 5th harmonic. Batteries smoothed it right out. Three "D" size flashlight batteries should last quite a while since the drain at 4.5 volts is 3 ma. This figures out to a total



The heart of the VFO, L1, a permeability tuned coil wound on thick plastic stock.



View of the transistors in the VFO. Note the solid construction.

power input to the VFO of 13.5 milliwatts, which is one of the main reasons for the stability. There's practically no internal heating.

The inductor

To keep changes in the box from stretching the coil from the inductor is constructed to be supported by the box at only one point.

The slug, which gave the inspiration for this mode of construction, is from an old ferriloopstick broadcast coil ¼" in diameter, with a 4-40 screw on one end, and a hole the right size to take a 4-40 screw in the other.

The bass and uprights were constructed from rectangular plastic stock ⅜" x ½". The coil form itself is ⅜" round plastic. A hole ¼" in diameter was drilled through the center of the coil form and then smoothed slightly by wrapping fine sandpaper around a smaller drill and working it back and forth until the slug slid easily through the form. When plastic is drilled with a high speed drill it tends to grab and melt and otherwise behave badly, so the drilling should not be rushed. The centering of the hole exactly is not extremely important, but it should be straight and as parallel to the form as possible. One end support was then glued on with polystyrene cement and the ¼" hole continued through the coil form through the support. (Let the cement harden thoroughly first.) Both supports are then glued to the base and the coil form glued to the other support. After drying, the hole is drilled back through the first support and coil form and through the remaining support. This way, all the holes line up exactly.

A 4-40 nut is then put on the screw in the slug and the slug is slid into the form. The nut is then heated with a soldering iron until it melts securely into the support. Another 4-40 screw, at least two inches long is then threaded an inch or so into a nut, and ¼" or so of its threaded end is liberally smeared with epoxy cement. The hole in the slug is also smeared on the inside with epoxy cement for about ¼". (A toothpick serves well.) The slug, in the coil form, should then be positioned so that when the nut on the two inch screw is melted into the remaining end the screw will go into the hole for about the ¼" that has been glued.

Once assembled in this fashion, the nuts, screws and form will be in alignment, and the slug should revolve freely for ¼" or more of travel inside the form. Unfortunately, once assembled in this fashion, it is impossible to take the assembly apart without breaking something, so be careful!

This may sound involved, but once the drilling of the form and supports is completed and the plastic cement has hardened, the remaining steps take about as long as it takes to tell about them. The important thing is the order of assembly—which should be fairly obvious.

The coupling from the dial to the inductor is a piece of tubing with an inside diameter that the 4-40 screw on the slug will slide inside. The tubing is slotted (with a coping saw) on one end, and built up with wire on the other to fit the ¼" hole in the dial. A short strap is soldered into the slot in the screw on the slug. This strap rides in the slot as the slug rides in and out and serves to transmit the circular motion from the dial to the slug. This method of construction also avoids transmitting any lateral motion to the slug due to the expansion of the case from heat.

The winding was put on the form and cemented with Q-dope It gives 35 kc at one end of the range (5 mc) and 50 kc at the other end (5.8 mc) with the winding as shown. Further adjustment of the spacing of the winding before gluing would

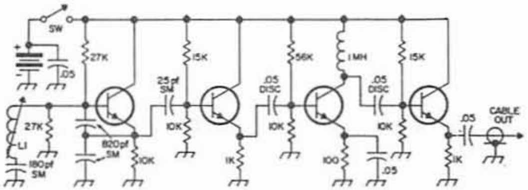


Fig. 1. A Home Brew Permeability Tuned VFO. See text for L1. All transistors are 2N708. Battery voltage is not critical; a 4.2 volt mercury battery is recommended for best performance.

have improved that. This particular frequency range mixes with my 9 mc filter output for eventual use at 50 mc.

The winding in use is twenty-seven turns of #22 enamelled wire. The first ten turns are close-wound, and the next seventeen with gradually increasing spacing. The spacing between the last few turns is about 3/16".

Results

The resulting tuned circuit is temperature sensitive because the dimensions of the ferrite slug are temperature sensitive. However, the input to all four transistors is around a tenth of a watt, and the oscillator shows no discernable drift caused by internal heating during operation.

If the temperature where the VFO is to be used is not steady, some form of temperature compensation should be employed. Negative temperature coefficient capacitors should do nicely here.

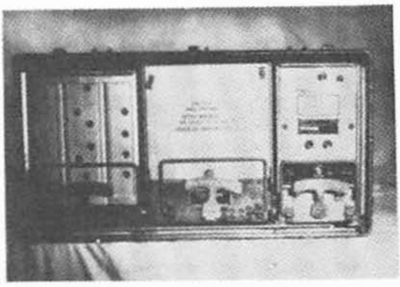
As currently constructed, the VFO has several drawbacks. There wasn't enough heavy aluminum available to build the box big enough to put a good turn-count dial on it. A ten turn Revodex dial has been tried, but is not entirely satisfactory. The output voltage is only a volt or so rms. For use with a mixer, this is enough voltage, but if the VFO is to drive a crystal oscillator stage, another stage of amplification will be needed. The input resistor in the grid circuit of such an amplifier stage could be 100 ohms or so, thereby removing the necessity for neutralization.

. . . W4VRV

Converting the AN-VRC-19 Transceiver

Recently there has appeared on the surplus market, and through MARS channels large quantities of a unique vhf FM transceiver called the AN/VRC-19. The three versions of this set all cover the same frequency range (152-174 mhz), but they differ in their input power requirements. The most commonly encountered version is the AN/VRC-19 X which is the 12 volt model. The set consists of a single case containing a transmitter (T-278/U), receiver (R-394) and a dynamoter power supply. It was originally designed for use in military police vehicles and other non tactical applications. It is of 1950 vintage having numerous sub miniature tubes. Typically, the sets are found without the control head or manual.

Basically, the set is a wide band (15 khz deviation) single channel crystal controlled transceiver with a 30 watt output. The transmitter has provision for operation on two channels providing that they don't differ by more than 500 khz. However, this feature was seldom used and most of the transmitters will be found with the channel 2 1AD4 oscillator tube missing. Also, don't worry if you see a hole for a missing module in the receiver. This is for the re-transmission relay which is normally not supplied.



The AN/VRC-19 with the front cover removed. The receiver is the unit on the left.

Getting the set on the air consists of solving two problems wiring in the controls, and obtaining power. We will assume that you will use the set mobile from a 12 volt battery.

The fastest way to get on the air is to get a C-847/U control head and apply 12 vdc (at 24 amps on transmit) to terminals 1 and 2 of J-806. The control head has two terminal boards inside. TB-1501 and TB-1502. The terminals on these boards are numbered 1 through 20. Connect these to terminals 1 through 20 of TB-804 and TB-805 in the case (see Fig. 1). The C-847 head is rare, so the circuit shown in Fig. 2 was built to replace it. The controls including a 3" speaker were mounted on a 5¼ EIA panel.

After assembling and wiring the control panel, you will have to obtain the proper crystals. These should be CR-27's for the transmitter, calibrated for a 32 pf circuit. The receiver uses CR-32 third overtone crystals. The transmitter crystal frequency is obtained by dividing the desired output frequency by 32. The receiver crystal frequency is calculated by:

Crystal freq.=desired frequency(mhz)-7.8/6.

The receiver crystal oven assembly is located in the local oscillator module.

Receiver alignment

After installing the receiver crystal in the oven, turn the power on and allow the receiver to warm up for 15 minutes. Connect vtvm between the LO and GND test points. Adjust the four slugs on the local oscillator module (Z-31, Z-32, Z-33, and Z-34) for maximum negative voltage.

Next, move the vtvm probe to the 2nd *if* test point. Connect a signal generator to the antenna connector and tune it to the desired operating frequency. Adjust the five slugs on the *rf* amplifier module for maximum negative reading on the vtvm while keeping the

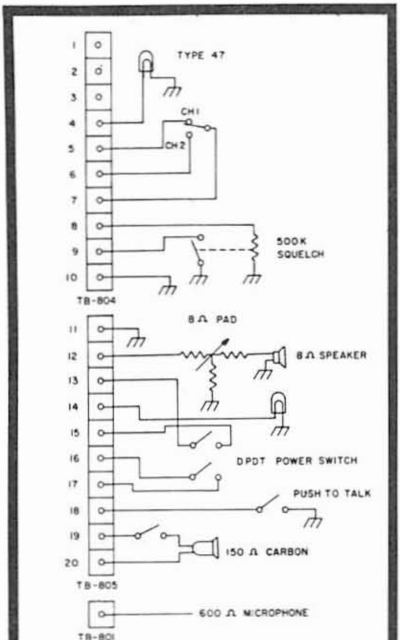


Fig. 1. Control Schematic For AN/VRC-19 Transceiver.

signal generator output as low as possible.

Precise adjustment of the receiver frequency can be obtained, after the above alignment, by connecting the vtvm between DISC and GND test points and adjusting Z-31 (top slug in the local oscillator module) for zero reading on the vtvm when receiving the desired frequency.

Transmitter tune up

First get your hands on cable assembly CX-2371, or build a jumper cable 30" long so that you can work on the transmitter out of the case. Without this it is impossible to align the transmitter.

Remove the dust covers from the transmitter and turn the set on, allowing it to warm up for at least 15 minutes. Set the channel selector switch to channel 1. Turn the coupling control to minimum and place the Tune/Operate switch in the tune position. Set capacitors C-403 and C-404 to their mid point positions. The test/off switch is used to control the transmitter during the alignment procedure. Do not operate the transmitter for more than a few minutes at a time or the dynamotor will overheat.

Place the vtvm probe in J-401 and adjust Z-401 for maximum deflection. Then back it off until it is reduced to 2/3 of its maximum value. The reading should be approximately - 3.5 volts. Next, place the probe in J-402, 403 and 404, adjusting Z-402, Z-403 and Z-404 sequentially for maximum deflection. Place the probe in J-405. Set Z-405 to approximately the same physical setting as Z-404. Adjust C-429 for a maximum reading, then peak using Z-405. Repeat as these controls interact. Replace the dust covers and reinstall the transmitter in the cabinet.

Place the vtvm probe in the driver grid jack and adjust the final grid tuning capacitors C-437 and C-439, and the driver plate tuning capacitor C-436 for maximum.

Set the tune operate switch to the operate position. Place the vtvm across the PL CUR jacks and connect the antenna or dummy load. 2.5 volts is equivalent to 100 ma. Dip the final tank using the plate tuning control, and adjust the antenna tuning capacitor for maximum plate current. Increase the antenna coupling while repeating the adjustments of the plate tuning and antenna tuning controls until the plate current reaches 140 ma. Connect the vtvm across the BAL test points. The reading should be 0. If there is a deflection, adjust the final grid controls until a zero reading is obtained.

Precise adjustment of transmitter frequency can be accomplished using C-403 for channel 1 and C-404 for channel 2.

The set is now ready for operation. This set has a unique re-transmission feature enabling it to operate as a repeater. This requires installation of relay assembly K-271, to be plugged into the empty cell in the receiver, and terminals 1 and 10 and 2 and 9 of TB-801 to be jumpered. If you use the set in this mode be sure the squelch is operating, or the transmitter will transmit constantly.

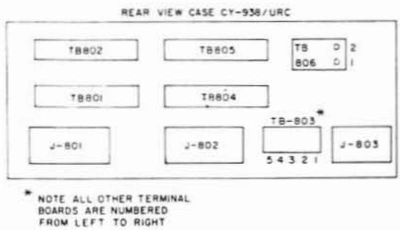


Fig. 2. Terminal Board Locations.

As a matter of interest, the receiver can be used on 60 hz, without modification, simply by unplugging the vibrator and fuse and applying 6.3 vac 4 amps to terminals 4 and 5 of PP-867/U. The transformer is designed for 95 hz operation and the 6.3 V winding is rated at only 1 amp, but it is husky enough.

There is a 110 V power supply available for this set. The receiver uses a PP-846/U and the dynamotor assembly is replaced by a PP-804/U supply. If these supplies are available, it is simply a matter of applying 115 V 60 hz to terminals 4 and 5 of TB-803.

The unit on hand was tuned to operate on 148.01 mhz without any circuit changes. Judging by the settings on the controls, it should be possible to cover the upper portion of 2 meters without padding. Additional information can be found in TM-11-297, the technical manual for the set.

...W6JTT

Six for Six Antenna

As all hams know, activity on six has been very high since the band was opened to Technicians. Any one who is determined can learn enough to pass a Tech license test in a fairly short time. So now this is the second largest class of licenses and most active Techs are on six. This has caused a lot of QRM on the band; only the best equipment is useful for fighting the other stations, particularly for DX.

This antenna was built for high gain to provide excellent performance on six. It's a wide spaced six element yagi on a 24 foot boom. It's made of aluminum for lightness, low cost and easy construction. The SWR is excellent over the most used part of the band.

Each element is about a half wave long. The exact length can best be found by experimenting. The distance between the elements can also be adjusted for best results, a compromise between gain, side lobes, front-to-back ratio, SWR, etc. The dimensions given worked very well for me and are a good starting point.

Unfortunately, 24 foot aluminum poles for the boom are hard to find. I used two twelve foot 1¼ inch 0.058 wall poles and butted them together with an eight foot 1⅛ inch dowel in the center furnishing strength. A short piece of 1⅜ inch tubing over the joint gives electrical continuity.

The elements are held on with Cesco Large Yagi Clamps. If you can't locate them, you might try improvising from broken TV antennas, etc. I made each element a little short and slid a length of ⅝ inch tubing in each end for accurate adjustment of length.

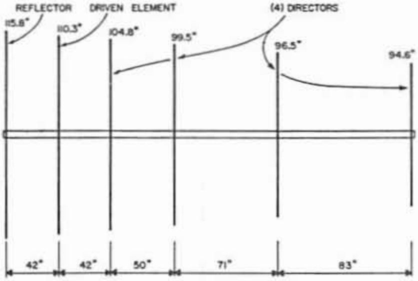


Fig. 1. Dimensions of the six element yagi.

A wide spaced antenna such as this one has a fairly high feed impedance—at least compared to close spaced beams. There are a number of different matching systems that you can use.

Take a quarter wave length of RG-58/U. Find its center. Remove one inch of insulation at the center. Carefully cut the shield apart, but leave the insulation and center conductor intact. Gather the pieces of shield together and

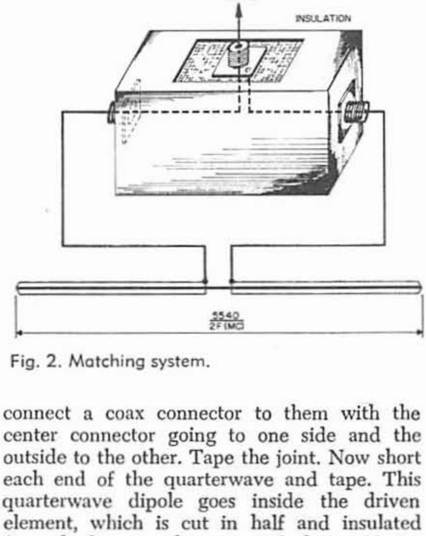
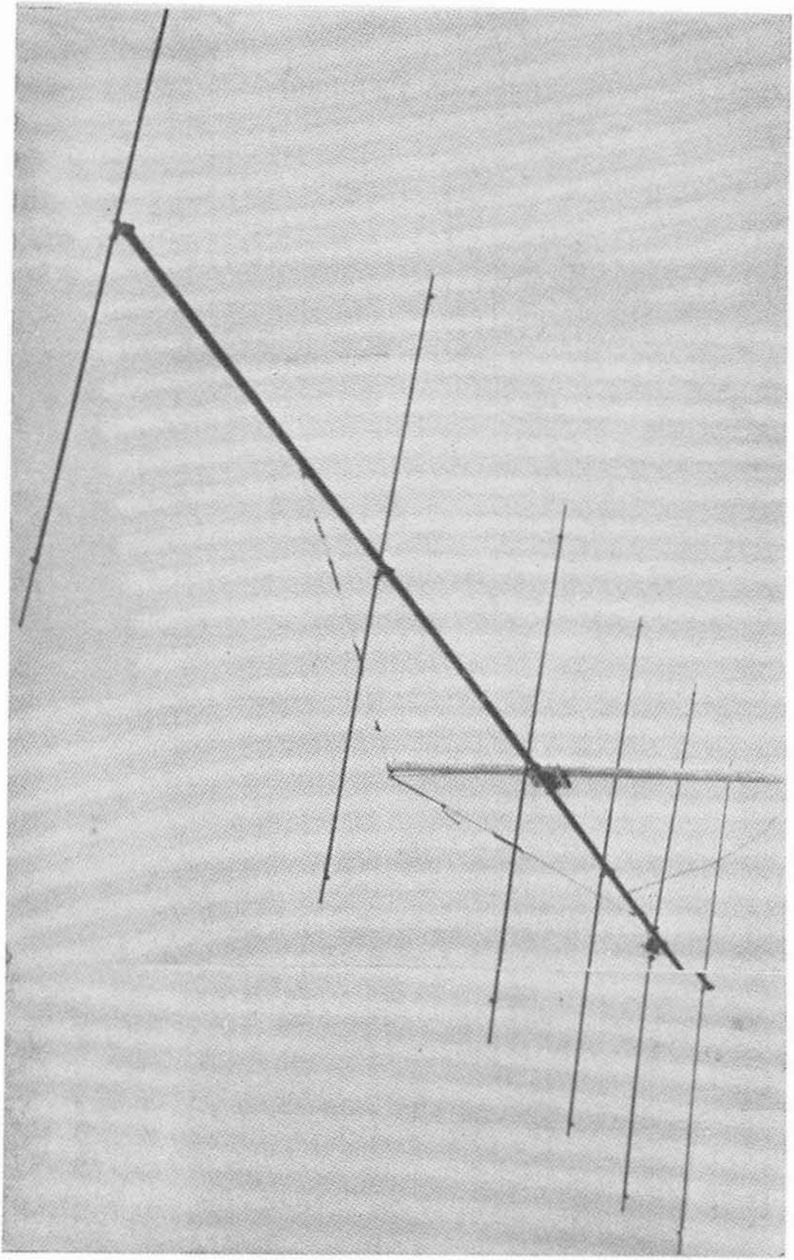


Fig. 2. Matching system.

connect a coax connector to them with the center connector going to one side and the outside to the other. Tape the joint. Now short each end of the quarterwave and tape. This quarterwave dipole goes inside the driven element, which is cut in half and insulated from the boom with a piece of plastic. Notice that there is no direct connection to the driven element.

Mount the antenna at its center of balance with a home-brew wooden mast mount or with a Cesco mount. I added two wire supports from above the antenna to the boom to prevent sag. Break these cables with egg insulators to prevent unwanted resonances messing up the pattern of the beam. Adjust the element lengths for minimum SWR and you're ready to go.

. . . WB2CQM



Superimposing 6 Meters on a Tribander

Now that SSB transmitting converters are firmly fixed on the scene, many amateurs are faced with the erection of another antenna or beam. While there is no argument against the efficiency that will be obtained when a beam is designed for a specific frequency and independent from other arrays, many cliff dwellers and others just in a hurry can take advantage of this shortcut which adds little or no weight or cost to the operation.

We have long been familiar with the technique of tying resonant lengths of antennas to a common low impedance feedline, and the popular trap triband yagis have this point in their favor. Several factors enhance the addition of superimposing a six meter beam to the multiband antenna. One is that six is not harmonically related to these bands, thus not disturbing or being disturbed by the lower frequency lengths. These lower frequency antennas at their current points will now present a high impedance to the six meter portion when operating on six. Another factor is that closed spaced arrays predominate the multiband beam system, permitting six meter operation using the non-critical quarter wave spacing between elements at that frequency. This factor means less critical adjustment of lengths, broadbanding and retention of coax line impedances.

The theory behind the superimposition is that part of the original elements are used for a quarter wavelength around the current feed point of the antenna. Electrical resonance for six, and decoupling from the balance of the

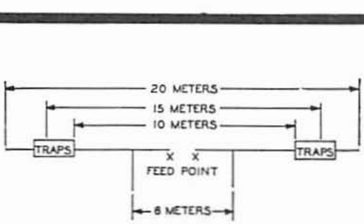


FIGURE 1

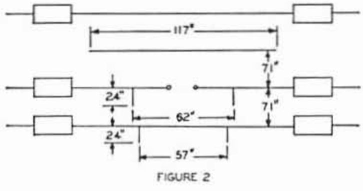


FIGURE 2

antenna is achieved by "drooping" ⅛th wavelength at each end of this quarter wave, thus forming an electrical half wavelength circuit.

In order to visualize the physical structure, Fig. 1 illustrates a triband radiator element, in this case a Mosely TA-33, to which a six meter resonance is superimposed.

The final installation is shown in Fig. 2. The drops for the radiator and director for 50 mc are composed of 26″ lengths of TV aluminum No. 8 ground wire, two inches being bent at right angles and inserted through hose clamps which grip the wire and basic antenna element. The wire is oriented to hang downwards. Aluminum rod could be used, but the short length of wire presented no problem in the installation.

Since the reflector in this arrangement was more than a quarter wavelength on six from the radiator, it was decided to add a reflector element. Obviously, an additional close spaced director element could be added to make a four element array from the system.

The dimensions for 50.0 mc are a total of 110 inches for the radiator, consisting of the hose clamps spaced 62 inches apart, equidistant from the common feedpoint center line, electrically completed in resonance with the two 24″ drops. The director is 105 inches, using a 57 inch separation between hose clamps, also with two 24″ drops. The reflector is a half-inch diameter piece of aluminum tubing 117 inches in length, and 71 inches behind the reflector.

If an additional director were to be used, a 105 inch piece of tubing could be placed halfway between the original director and radiator, and the triband director, now the second,

would be a total of 104 inches or 56″ between drops.

Obviously this is not the only application to which the superimposition system could be used, nor may these be ideal lengths and spacing for every situation and antenna. The system, of course, could be used with various types of antennas and for various frequencies. This should provide a fertile field limited only by the imagaination and application of the experimenter.

. . . W4API

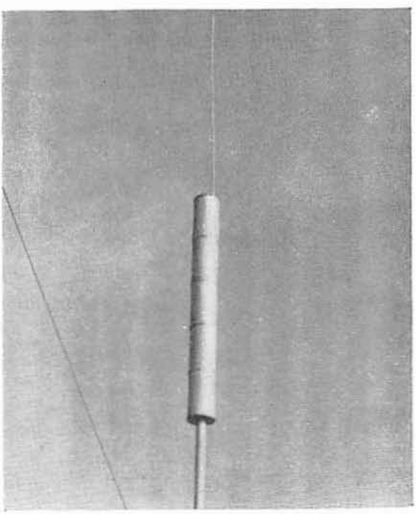
Two-Meter Antennas

Here are two easy-to-build antennas for two meters. Either can be used for fixed or mobile operation, but I prefer the 'J' on the car, and the coaxial (or sleeve) antenna on the house.

The J is popular for mobile operation. One drawback to the antenna is that it can sometimes be difficult to construct and cumbersome in appearance. The W6TKA-J eliminates those problems. The mounting for the J consists simply of an aluminum bracket bent in the shape shown in the drawing and photograph, with a UHF-type coaxial panel connector mounted on the bracket. The bracket is held in place just inside the trunk lid by two sheet metal screws. A single hole through the lip of the trunk opening takes care of the RG-59/U cable running to the transmitter. Thus, no noticeable holes have to be drilled in the car to mount the antenna. Also, please note that this J is fed directly at the base with coax, and not at a 300-ohm point through a bulky balun.

It might be well to explain that the J is nothing more than a half-wave antenna fed with a quarter-wave matching section, consisting of the lower 19-inch section with the longer element spaced something less than two inches away. The J is *not* a three-quarter wave antenna, as I have occasionally heard it described. The lower 19 inches of the element that becomes the antenna and the second, grounded 19-inch section, do not radiate. As a matter of fact, if the long radiating portion of the antenna were bent at a 90° angle to the matching section, you'd have the old-fashioned "end-fed Zepp."

W6TKA-J Mounted on Car



Completed Coaxial Antenna

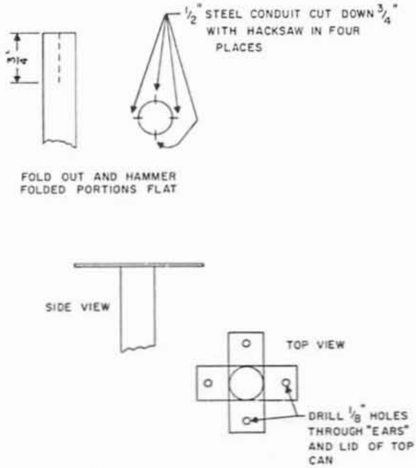
The antenna is built around a PL-259 UHF-type coaxial connector. Both elements are ⅛ inch half-hard brass rod, available from almost any metal supply house. Dimensions for the two elements are given in Table I.

The long piece of rod must be carefully filed until it will slip into the pin of the coaxial connector. The filed end of the rod and the inside of the connector pin are then tinned, and the rod "sweated" into place. Do not force the rod into the connector or the connector insulation may fracture.

Next, the shorter element is prepared. Make a 90° bend 2¼ inches from one end of the rod.

TABLE 1
"J" Antenna Dimensions

Frequency, Mcs	Length, In., Short Section after bending	Length, In., Long Section above connector
144	19¼	38½
145	19⅛	38⅛
146	19	38
147	18¾	37¾
148	18⅝	37½



DETAIL OF END OF CONDUIT PREPARATION FOR MOUNTING COAXIAL SLEEVE. REFER TO TEXT.

See Table I for the correct rod length. Then bend the last 1¼ inches of the 2½ inch section into a semi-circle of the same inside diameter as the outside diameter of the upper portion of the connector. Tin both the upper part of the connector and the loop that you have formed, and solder into place. At this point the shorter element will be spaced between 1½ and 1¾ inches from the longer element.

The upper part of the connector is now packed with small pieces of polystyrene foam, taking care to keep the antenna centered within the plug. Then, when the foam has been tightly tamped into place, use polystyrene cement to disolve the plastic. When dried, you will have a low-loss insulator which will keep the antenna centered in the plug.

To maintain the correct spacing between the elements over the entire length of the shorter element, a piece of plastic rod the same length as the spacing between the elements (as measured just above the connector) is placed near the top of the shorter element. In our case we used a plastic spreader taken from 450-ohm TV open-wire line. About ¾ inch of the TV wire was left extending on both sides of the insulator, and the wires twisted around the two antenna elements, and then held in place with plastic electrical tape. As a finishing touch, the entire antenna (except for the insulator and the connector, which were masked with masking tape) was spray painted aluminum, and the plastic tips

TABLE II
Coaxial Antenna Dimensions
(Same dimensions apply to both sleeve and radiator)

Frequency, Mcs	Length, In.
144	19¼
145	19⅛
146	19
147	18¾
148	18⅝

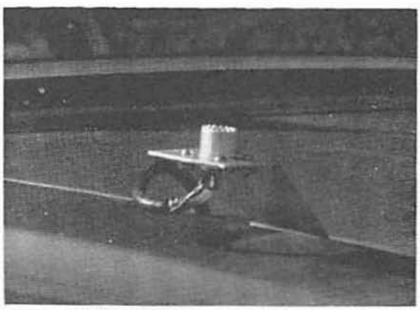
from an old "rabbit ears" indoor TV antenna were placed on the ends of the two elements.

The antenna is easily removed when garaging the car, and has little wind resistance. Best DX to date—with one watt output from the transmitter—was a station in San Diego, California, contacted while driving through downtown Los Angeles—a distance of some 100 miles.

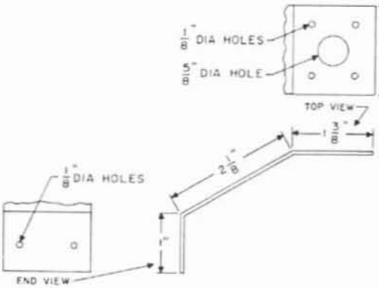
Now for the coaxial vertical antenna. There we used frozen orange juice cans (yes, other flavors will work!), and soldered them together. Five cans, each 3¾ inches long, with both ends removed (except for the top can, which has one end left in) were used to make up the sleeve. Using tin shears, the lower can is trimmed so that the overall sleeve length corresponds to the dimensions given in Table II. One word of caution: not all frozen juice cans are steel. Some are aluminum—even within the same brand we found both metals being used—so choose the cans with care. If a can won't solder, chances are it is not steel.

A small ceramic feed-through insulator (E. F. Johnson No. 135-44) was installed in a hole drilled in the top can lid, and the center conductor of RG-59/u coaxial cable connected to the insulator stud. The braid of the coaxial cable is soldered to the inside of the top can.

Next, take a ten-foot length of one-half inch steel "thin-wall" steel conduit, available at hardware or electrical supply stores. Split one end using a hacksaw as shown in the sketch. Feed the coaxial cable down through the conduit and out the other end. Then fold



Mobile J Antenna Mounting Bracket



J ANTENNA MOUNTING BRACKET

back the slit portions of the conduit so that it will fit tightly into the end of the can in which you have installed the insulator. Then drill at least two holes from the lid side of the can through the lid and through the split portions of the conduit. Use sheet metal screws to hold the lid in place.

The next problem is soldering the cans together—which really isn't much of a problem if you have a good 100 watt iron, *non-corrosive* soldering flux, and resin core solder. First, "tack" each can in place with solder at about four places around the periphery of the can. Then go back and solder heavily all the way around. I laid the assembled portion of the antenna flat and held the cans between stacks of old books.

When you finish, you should have something that looks like the antenna shown in the photograph—except, of course, for the radiator itself, which we have not yet installed. Now take a piece of polystyrene foam and cut it circularly the size of the inside diameter of the lower can. Make the foam just a little oversize, so it will fit tightly. Then, cut the piece of foam in two, cut a semi-circle in each half for the conduit, and put the two pieces in place to hold the end of the assembled sleeve equidistant from the conduit.

Now cut a piece of aluminum clothesline wire (see Table II for correct length). Make a 90° bend in the wire at a point one-half inch from one end. Then bend the one-half inch portion into a semi-circle so it can be attached to the insulator. It will probably be necessary to use two ¼-inch washers on the insulator to attach the antenna securely.

And that's the coaxial antenna. Just mount it where you want it, by means of clamps to a mast or the side of the house, run the coax where you want it, and you're on the air.

With the J on the car and the coaxial on the house, you can drive around the block talking to yourself!

. . . W6TKA

Wide-Band, High-Gain Antenna

The goal of every Amateur so far as an antenna is concerned is to have one that will give a respectable gain; is relatively small in size; can be fed directly by a standard feedline; is easily constructed without recourse to off-beat materials or parts; is cheap; and will give the same performance, especially input impedance and radiation pattern, over a wide band of frequencies.

Such an antenna is the Log-Periodic, the principles and initial design of which were first investigated by Dr. DuHamel in 1956. Other experimenters followed and one of the designs evolved was the Log-Periodic Dipole. A study of the different types brings the conclusion that his is the most practical design for amateur consideration. Basically, the antenna consists of a number of parallel, linear dipoles arranged side-by-side in a plane. The lengths of the elements, the spacing between them and the dimensions of the boom are all determined from a series of mathematical formulas. Full details on the theory and design can be found in Dr. Carrell's report, *Analysis and Design of the Log-Periodic Dipole Antenna*, and anyone wishing to adapt this design to his own needs should obtain a copy.

The Log-Periodic Dipole described here covers the frequency range of 140-150 mc, having a gain of 10 db over a reference half-wave dipole, and directly fed

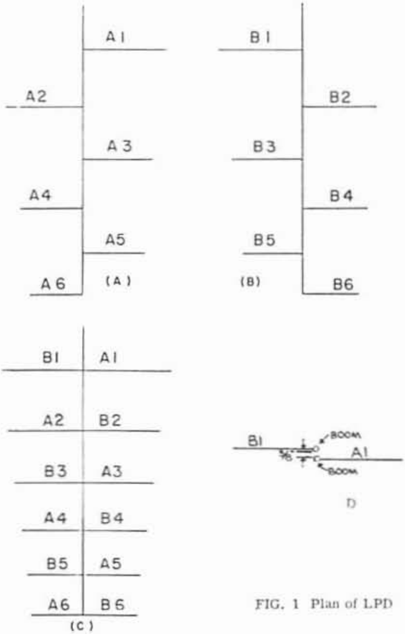


FIG. 1 Plan of LPD

The finished antenna

with 72 ohm coax cable. Over the range, the swr is less than 1.5:1, the E-plane beamwidth is approximately 47° and the H-plane beamwidth 85°. The booms are made from ¾ inch, the elements from ¼ inch aluminum tubing (recommended type 65ST6) and each element is fastened to its boom with a 3 inch TV standoff pipe clamp. There are six dipole elements and Fig. 1 a-d shows the plan of each section and how they are combined into one array. Table I gives the lengths of each element and their spacing from the feedpoint which is the end with the No. 6 element.

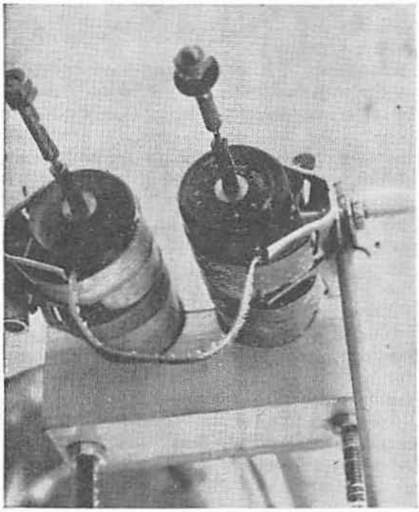
The boom length is 72 inches so that the boom will project past the last element 11.7 inches. The two booms are shorted together at this point (see Fig. 2).

Table I—Dimensions of LPD array

	Length of Element	Spacing from Feed-point
A1 = B1	20.8 in.	60.3 in.
A2 = B2	19.0	46.0
A3 = B3	17.4	33.0
A4 = B4	16.0	21.0
A5 = B5	14.6	10.0
A6 = B6	13.3	0

The antenna is fed with 72 ohm coax cable at the feed-point, with the center conductor attached to one boom and the outer sheath to the other boom. It is recommended that the coax be inserted in the lower boom as shown in Fig. 4 but it can be taped under the lower boom with only a slight decrease in performance.

The two booms are separated by a distance of ⅜ inches throughout their length. This is done by making two separators and one mounting block. Wood, preferably hardwood, can be used for this. Two pieces of 2 x 2 lumber, 3½ inches long and one piece of 2 x 4 lumber 6 inches long, are required. Two ¾ inch holes are drilled centrally in each block, spaced 1 ⅜ inches center-to-center in the 2 inch face. Two additional ¼ inch holes are made in the blocks so they can be clamped together when sawed apart, as shown in Fig. 3. The boom is clamped by the three blocks, and holes are drilled in the center 2 x 4 block to accommodate two TV mast U-clamps on the 4 inch face. All the wooden parts are then coated with 2 to 3 coats of exterior varnish.



Feed point of the antenna and view of the first element and separator block.

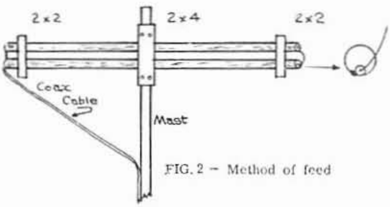
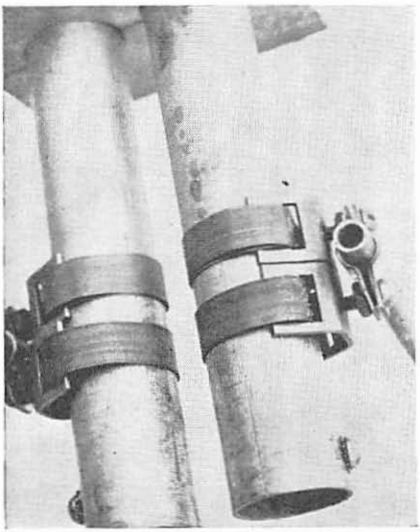


FIG. 2 – Method of feed



Our first attempts at securing the elements to the booms were very satisfactory but more costly than the method outlined

The elements are held onto the boom as shown in Fig. 4. The 3 inch TV stand-off is threaded to the pipe clamp on the boom. The end is cut off and the ¾ inch element is put on over the stand-off extension. If 0.035 inch wall tubing is used, you can now thread the tubing over the ½ inch or so of thread that projects past the clamp. If thinner wall is

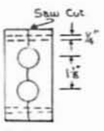


FIG. 3 Separator block

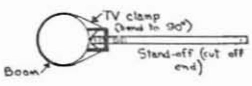


FIG. 4 Attaching Stand-off

used, crimp the ends slightly so the thread will bite and if wall is too thick, drill to the proper diameter.

Antennas built as described have been built in this area and have not yet failed to live up to calculated performance. The mechanical construction has been successfully used down to 50 mc and the antennas have withstood severe icing conditions and gale force winds. But experience has shown that a different method of clamping tubing to the booms is necessary below this frequency. One approach might be to drill the boom and insert the element through the boom with some suitable method of clamping, but no research has been done as yet in this direction. ~~I have~~ calculated the dimensions of a tri-band beam for operation in the 20, 15, and 10 meter bands, fed with 72 ohm coax, to give a gain of 7 db on all frequencies within the bands with a swr less than 1.5:1. This would be constructed using 1½ inch tubing for the booms—each 20 feet long—and ¾ and ½ inch tubing for the elements with longest dipole element 33.5 feet long.

The Log-Periodic principle, in practice, will give an antenna that is frequency independent over large bandwidths with frequency ratios of 10:1 being easily obtained. One antenna constructed and in use has a gain of 8 db over a frequency range of 50 to 250 mc, a boom length of 10 feet, and is fed with 300 ohm twinlead with an swr of less than 1.5:1. This has been used for amateur operation on the 6, 2, and 1 ¼ meter bands, and for TV (all VHF channels) and FM broadcast reception.

We wish to thank Dr. Carrell of Collins Radio for his assistance and permission to use certain parts of his reports and the gang in Kingston who rendered invaluable assistance in trying out these designs.

. . . VE3AHU

Two-Meter Groundplane Antenna

A groundplane is a unity-gain, omnidirectional antenna.

So much for Lesson 1. The meat of this section, Lesson 2, will shoot down what you learned in Lesson 1. Because virtually any vertically polarized omnidirectional antenna can be used to provide gain and directivity *selectively*—without modification of the antenna itself.

To many, a true omnidirectional antenna represents the optimum approach. For the amateur who operates in the center of a metropolitan area, or the hilltop ham, or the centrally located net control—what could be better? But—what about the guy who lives between two cities and wants good, broad coverage in only two directions? Or the fellow at the foot of the hill who wastes all that rf by dumping half his output into it?

An omnidirectional antenna can still be the answer, but employed to provide gain where the action is.

The secret is not in the antenna itself, but rather in the mounting of the antenna. *Don't mount it atop a mast.* Place it near the top of a mast or tower, and adjacent to it so that the tower or mast itself becomes a part of your antenna system. Learn two simple rules and you can design your omnidirectional antenna to give gain in practically any direction or directions you choose: The first rule is that for each quarter wavelength you space the vertical radiator of the antenna from the tower or mast, you get one major lobe. And the second rule: The bigger the mass of the supporting structure, the wider the frontal and side lobes. Consider the radiation pattern of **Fig. 1.** The solid round dot at the center represents an antenna supporting structure. If an omnidirectional antenna were mounted at the top of the structure, the pattern would be roughly circular. The broken line represents this pattern at a relative field strength of 1.0. If the same antenna were to be moved from the top to the front of the tower and spaced a quarter wavelength from it, the pattern becomes more or less like that of the heavy asymmetrical line. (This is assuming the tower is between eight inches and a foot in diameter adjacent to where the antenna is mounted.) In the sketch, the antenna is represented by the small circle above the center dot.

As shown, the result is an excellent 180-degree signal with no wasted rf off the back. And the bonus is a 30-percent increase in signal strength over 150 degrees of that half-circle. Naturally, this city-side amateur isn't getting something for nothing; whatever he gains in one place, he loses in another. This can be demonstrated by thinking of the broken line in the sketch as a closed loop of string. You can manipulate the string and change the configuration of it, but for all practical purposes, the size remains the same.

For the amateur who wants good coverage in two general areas spaced roughly 180 degrees apart, the best approach would be to mount the antenna a full half-wavelength from the support structure. A typical radiation pattern from this mounting method is shown in **Fig. 2.** It should be borne in mind that the mass of the tower affects the

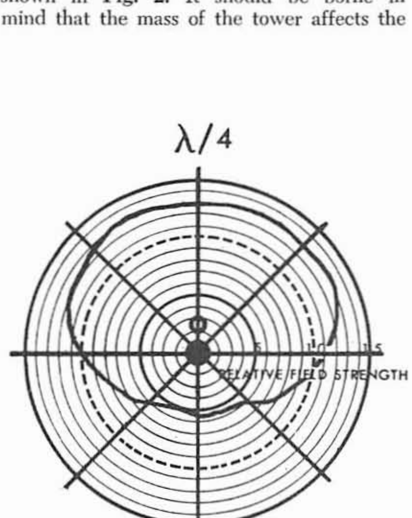


Fig. 1.

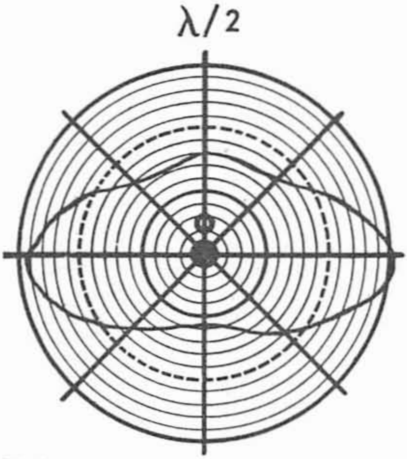


Fig. 2.

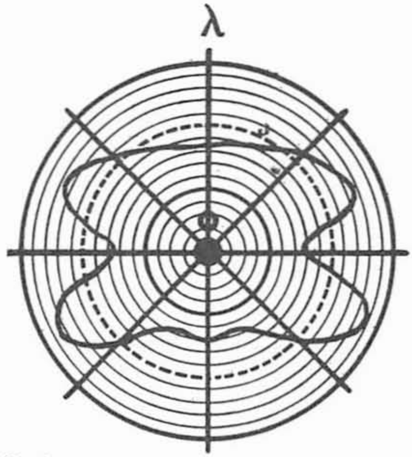


Fig. 4.

pattern substantially. A mast would yield a pattern with sharper, thinner lobes—more gain at the expense of horizontal angle of radiation. The half-wave pattern shows that the signal is reduced by 20 percent (from a top-mounted vertical) in a 90-degree area off the front of the antenna, and by about 35 percent in a 60-degree area off the back. But it is increased by as much as 150 percent laterally.

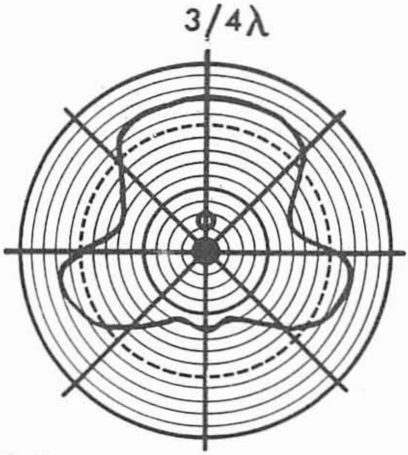


Fig. 3.

A sort of cloverleaf effect can be obtained by spacing the antenna three quarter-wavelengths from the tower. As shown in **Fig. 3**, it results in a very broad frontal lobe with uniform gain over about 80 degrees. The two nulls slightly forward of both sides is compensated for by the gain just rearward of both sides.

It is probably impractical to consider mounting the antenna more than three quarter-waves from the tower. On two meters, a full wavelength would be in the neighborhood of six feet. But the sketch of **Fig. 4** gives a pretty good idea of what the pattern would look like.

The important thing is that the theory is not restricted to any frequency. The patterns remain the same regardless of whether the operation is on six meters or 420 MHz. And the radiation patterns gradually shift from one to the other, so by experimenting with varying spacings, practically any desired effect can be achieved.

. . . K6MVH

VHF Antennas

There is a great fascination in building and testing VHF antennas.

Which is better? Yagi or curtain-type beams. Curtain, or broadside, arrays always have a wider frequency coverage than arrays of yagi antennas and are generally easier to get into proper operation. Yagi arrays can be made with fewer elements for up to about 15 dB gain. Above that figure, large broadside antennas may have actually less antenna elements than equivalent arrays of yagis. When a person wants as much as 18 or 20 dB gain a large broadside array of from 64 to 128 elements may be easier to build and adjust than equivalent yagi arrays.

In terms of signal capture area or actual antenna gain, a great number of long yagi antennas will have no more gain than big broadside array. As the area spreads out for signal capture, the array depth becomes less and less important. The big broadside with thin depth may often wind up with more signal gain than long yagi arrays with great depth and "optimum" spacing. That word "optimum" is awfully hard to obtain in practice since director elements in a beam generally react unfavorably with adjacent broadside directors in other yagis.

Several years ago the writer made some tests on 1296 and later checked out again on 432 MHz. Various lengths of yagi antennas, adjusted for best forward gain into a field strength device with very low SWR on the transmission line were set up. The power into the transmission line and SWR were kept at a constant value by readjusting the matching stub and feeder taps whenever one or more directors were placed in the field broadside to the yagi. It is a time consuming job and took many days of work to check out some results. Even a single director element spaced out to the side (or sides for two) of from $\lambda/2$ to λ, produced a drop in forward gain. On the other hand, reflector elements spaced out about $\lambda/2$ always added to the forward gain when in the plane of the antenna element. Reflector elements can "work together" without losing gain whereas director elements usually do not. This occurs because a short element (director) tends to pull the field out in a direction away from the driven element more or less in a forward direction with respect to the director position. It means that any directors off to the sides, such as in two yagis, causes some loss in the desired forward gain. The expected 3 dB power gain for two yagis or 6 dB for four yagis is very difficult to realize. If the yagis are spaced far enough apart to pick up 3 dB forward lobe gain, the minor lobes become very large and the forward lobe begins to look like a cigar shape. The array may not be held in correct position in a strong wind.

It is better to have a fairly broad forward lobe for this reason. Strong side lobes mean undesirable noise and undesired signal pickup. "Noise" means all sources other than receiver internal noise.

Any two or more driven elements in a broadside beam (reflector and driven elements only) tend to produce objectionable "side" lobes as the spacing is increased much over $\lambda/2$. At λ or greater spacings the side lobes are horrible. Yagi arrays are usually spaced from λ to 3λ to avoid director interference effects and the side lobes are apt to be objectionable. If the spacing is reduced to about $\frac{5}{8}\lambda$, the side lobes are small but the forward gain may only be increased one or two decibels as the number of yagis are doubled. A good beam antenna should always increase 3 dB in gain as the number of elements is doubled, without increasing the side lobe problem.

One way of getting the desired 3 dB added gain for double the number of elements or rather double the area of beam dimensions, is to use closer spaced, short yagi antennas. The final end result in very high gain arrays, is that a driven element and a reflector will equal the results with a short yagi for each antenna unit. The short yagis of 8 to 16 in number can be used to advantage in fairly high gain arrays. Often four long yagis can be used to advantage for antennas with gains as high as 15 to 17 dB.

Scaling down proven long yagi designs from 144 to 432 MHz usually doesn't work out very well. The directors cannot be made ⅓ as small in length and diameter, spacing and boom support material. A variation in any of these items can make a 432 MHz yagi with low gain. Lots of work goes into the design and construction of a good 432 MHz yagi.

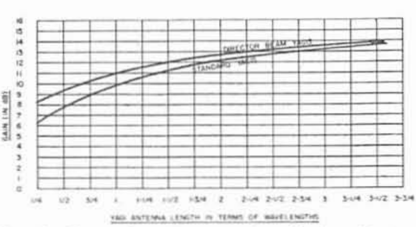


Fig. 1. Forward gain versus length for director beam and standard yagis.

Short or medium length yagi antennas can be made without reflectors and with a gain of about one decibel more than a standard yagi on the same mounting boom length. These yagi antennas are known as director beams since no reflector element is needed. The front to back ratio of lobes is similar to that of a standard yagi and may often be superior. The forward side lobes are quite similar to the standard yagi. The spacings for maximum gain between yagis is about equal to the boom length or higher, whereas the standard yagi spacing is usually from ¾ to 1 times the boom length. **Fig. 1** shows the forward gain which can be obtained from a single yagi of both designs. These are about maximum values which can be obtained in practical designs and it is very easy to get much less gain. It can be seen that the two curves begin to approach each other for long yagis.

Stacking two yagis in broadside will give from 2 to 3 dB more gain, with the smaller gain values occurring for smaller broadside spacing. The forward side lobes are always less for smaller spacings and usually a spacing of ⅝ to ¾ of the boom lengths, with only about 2 dB added forward gain, is worthwhile since the undesired lobes are much smaller and the forward lobe is broader. End stacking of yagis does not seem to be as critical, and close to 3 dB gain is obtainable with ¾ or greater length spacing. This holds true for any yagi design. Four yagis in a square configuration normally will add about 5 dB gain over a single yagi.

Broadside arrays generally use $\lambda/2$ lengths and spacings with a set of reflectors spaced .2 to .25 λ behind each driven element. The curves of **Fig. 2** indicate the approximate gain for the usual 4, 8, 16 and 32 driven element arrays with two sets of lengths and spacings. The ¾ λ spacing curve shows higher gain but it has greater forward side lobes and a sharper front lobe. For a given number of driven elements (and similar number of reflectors), the wider spacing and greater lengths add up to more capture area, and higher gain. Values from the curves show about 12 dB for an 8 driven element array of 16 elements for the usual lengths and spacings. The extended version has about 15 dB gain in a forward direction. Both arrays would use 8 reflectors of the same length in either design. The driven $\lambda/2$ elements are actually about 5% less length than the reflectors. In any case equal length phasing lines to all driven elements, can be made resonant and the whole array tuned to the desired band of frequencies with a quarter or half wave tuning stub at the common junction of these lines.

Three examples of practical beam antennas are shown in **Figs. 3, 4,** and **5.** These antennas have been in use at W6AJF for several years. The relatively small director beam of two yagis in **Fig. 3** is actually half of a larger beam which was cut in two in order to have a vertical and a horizontal 144 MHz beam on the same pole. The original square configuration had about 15 dB gain. Now each beam has about 12 dB gain but both polarizations are used in this area, so two beams are needed. This is a director beam with no reflectors and each yagi has about 10 dB gain. Two in broadside with relatively small spacing provides between 12 and 13 dB forward gain. An advantage of this beam is the simple feeder system, one phasing line and one tuning stub which can be either an open stub roughly 20 inches long or a shorted stub about 40 inches long. The latter is desirable as it can be grounded to the tower at the center of the shorting wire for added lightning protection. A 27 inch $\lambda/2$ balun and coax line connection can be made at point "C" in **Fig. 3** or a few inches above the shorted tuning stub for the $\lambda/2$ design. In any case the tuning stub is used to resonate the whole array to about 145 MHz with an accurate GDO while the antenna is a few feet above ground and pointing upward. The balun taps at "C" are also made at this time by using an SWR meter and transmitter. When the tuning stub is the right length and the balun taps are at the correct points, the SWR will be near unity at the desired frequency. Putting the antenna up in the air on a tower or TV mast will then prob-

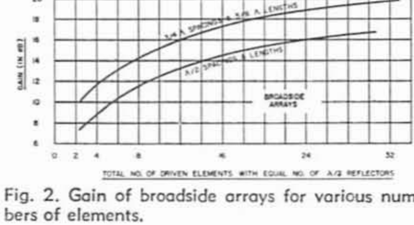


Fig. 2. Gain of broadside arrays for various numbers of elements.

ably raise the SWR reading to perhaps 1.2 which is within reasonable limits. This method saves a lot of mast climbing. The writer often uses TV push-up masts and makes these adjustments with the antennas in place but within reach from the roof of the radio shack. This requires considerable roof scrambling—an old story to this radio ham.

The antenna dimensions are all given in **Fig. 3** for the 144 MHz beam. Similarly, the values are shown for the 220 MHz beam in **Fig. 4** and 432 MHz in **Fig. 5**. All phasing lines and tuning stubs were made with number 14 wire spaced from ½ to 1 inch with poly insulators or Teflon insulators spaced 8 or 10 inches apart. Number 14 wire can be melted into the center of a short poly rod by holding a 150 or 200 watt soldering iron on the wire adjacent to the insulator. Teflon insulators require a hole smaller than number 14 wire and the wires forced thru these holes. Teflon is far better for foggy or rainy weather. The writer has no snow problem.

The 220 MHz beam of **Fig. 4** is a standard yagi design except that the rf feed is a little unusual and very simple. The driver elements of all four yagis are extended out to about ⅝ λ in length and end fed with a single phasing line and shorted tuning stub. The latter is a little over λ/4 in order to resonate the whole system to 222 MHz. The end spacing is limited to about 40 inches because of the ⅝ λ driven element lengths. For convenience the broadside spacing was also made about 40 inches. The antenna gain with four 4 ft. yagis (6 elements each) is approximately 14 dB which is about 2 dB more than could be obtained with a standard 16 element broadside beam. The latter requires more area space on a pole. Either two or four short or medium long yagis usually require less area space and provide more gain than a standard 16 element broadside of λ/2 design (see **Fig. 2** for eight driven elements).

Getting into high gain beams, such as needed on 432 MHz, the broadside beams come into preference usually. The one shown in **Fig. 5** was up for several years at W6AJF until poly insulator crazing, wind and bird collision damages forced its temporary retirement. It is due for an overhauling and substitution of Teflon insulators. It has an approximate gain of 18 dB when new and shiny. All 432 MHz beams tend to deteriorate from 1 to 3 dB with weathering, and corrosion of elements, so should be rebuilt and shined up occasionally.

The **Fig. 5** beam uses extended elements ⅝ λ long in the driven elements and λ/2 reflectors. The broadside spacing between driven elements is ¾ λ and the rear elements (reflectors) are about λ/4 behind the top portions of each driven element. The writer is not convinced that ⅝ λ broadside spacing is not better than ¾ λ because of less spurious lobe amplitudes. ⅝ λ spacing requires a different length of tuning stub and has about 1 dB less forward gain but the forward pattern is broader. The latter is an advantage in heavy winds, since horizontal directivity can be too

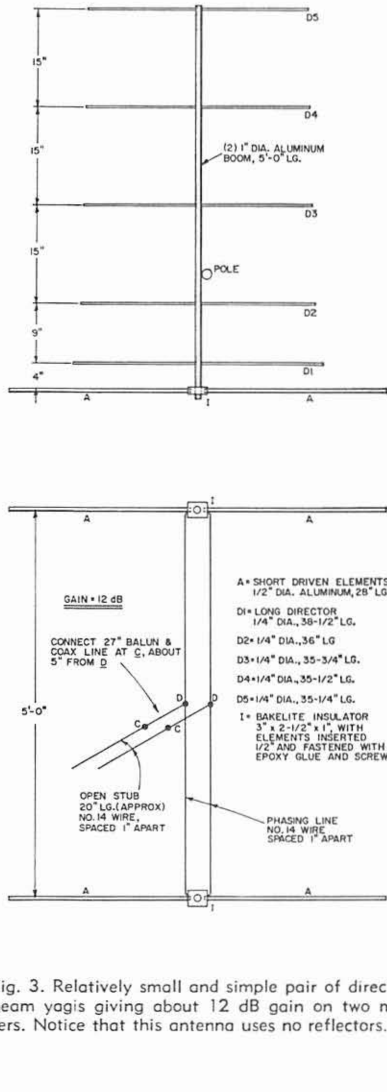
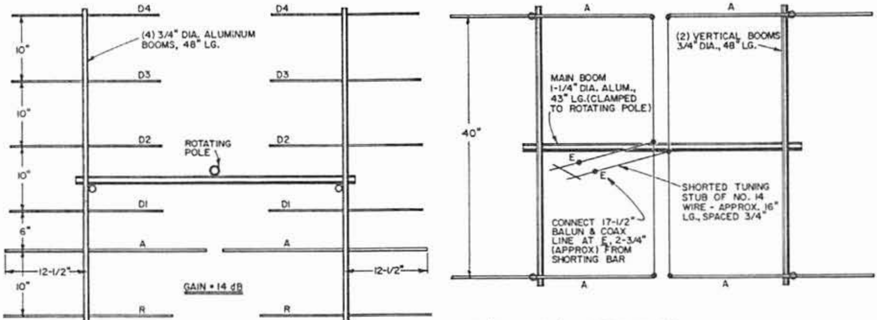


Fig. 3. Relatively small and simple pair of director beam yagis giving about 12 dB gain on two meters. Notice that this antenna uses no reflectors.



R = 1/8" DIA., 26-3/4" LG., CENTER-MOUNTED
A = 1/4" DIA., 31-1/4" LG., MOUNTED 12-1/2" FROM FREE END
D1 = 1/8" DIA., 23-3/4" LG., CENTER-MOUNTED
D2 = 1/8" DIA., 23-5/8" LG., " "
D3 = 1/8" DIA., 23-1/2" LG., " "
D4 = 1/8" DIA., 23-3/8" LG., " "

Fig. 4. 220 MHz quad of conventional yagis giving about 14 dB gain.

great for average ease of operation. An antenna much over two wavelengths wide can be a real problem to hold on a correct bearing for weak signal reception in windy locations.

The writer has a 64 element "curtain" beam on 432 MHz but with so much vertical stacking (32 over 32) the top of the beam moves several inches with respect to the bottom portion and a stiff wind adds considerable QSB to weak signals. The 64 element job uses ⅝ λ element spacing and its forward pattern is fine, better than the **Fig. 5** beam in practice. However, the top sway is a problem and the

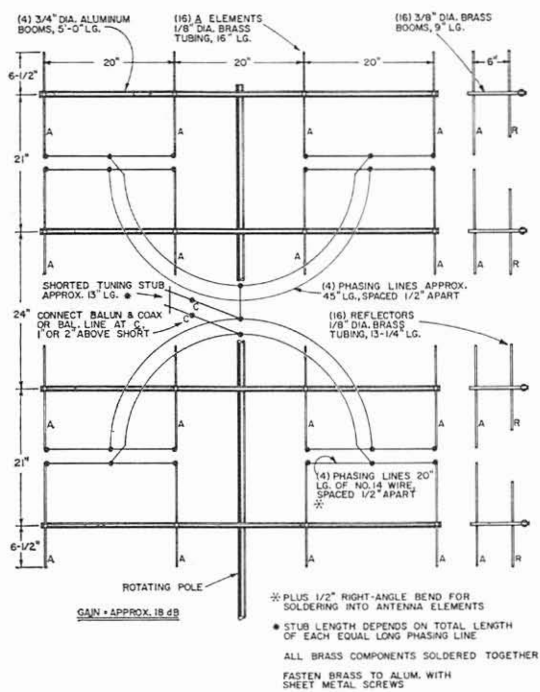


Fig. 5. High gain (18 dB) broadside beam for 432 MHz.

32 element job is going back up soon in place of the 64 element beam. The wind blows most of the time here and small beams seem to be preferable for everyday operation.

The three beams described here are all-metal construction which seem to stand wind and rainstorms better than wooden boom construction. Because of the metal booms supporting all radiating elements, the length of each element is slightly longer than for the case of wooden supports, especially in yagi antennas. The parasitic elements in all yagi beams have to be lengthened by about ⅔ of the metal boom diameter. If wooden booms are used, subtract this half inch or so from all parasitic elements (directors particularly) from the values shown. Don't expect other diameter elements than those shown to work correctly without some changes in lengths.

. . . W6AJF

Log Periodic Antennas Design

The log periodic antenna was originally designed and proved at the University of Illinois in 1955. Since then, the military has been making extensive use of this tremendously versatile antenna concept. Until recently, few in the amateur fraternity have known about the log periodic principle.

Through the use of computer-aided design, three such antennas for use in the amateur bands are described here. The dimensions for the three are given in Table I. All three antennas exhibit a forward gain of 13.5 dB with a front-to-back ratio of better than 15 dB over the specified frequency range. The swr is better than 1.8:1 over the specified frequencies.

The first antenna will cover the range of 21 to 55 MHz; the second antenna will cover 50 to 150 MHz; and the third covers 140 to 450 MHz. These antennas are designed with a 5% frequency overshoot at the low end and a 45% overshoot at the high-frequency end to maintain logarithmic response over the complete frequency range specified. In log periodic antenna operation, approximately four elements are active at any one specific frequency, thus the necessity for the low and high frequency extensions. All three antennas are designed for a feedline impedance of 50Ω for use with coax such as RG-8/U. All of the antennas are design-rated for 1 kW, 100% modulated. The alpha, or logarithmic element taper is 28 degrees for all three antennas.

Construction

Construction is straightforward, and you can use your own ingenuity as far as fastening the elements to the boom, and also the dielectric spacer configurations. I used heliarc welding for securing the elements, and fiber glass for the dielectric.

Element lengths for the highest frequency antenna were calculated for the elements to be inserted completely through the boom, flush with the far wall. The two lower frequency antennas have element lengths calculated to butt flush against the element side of the boom. If the elements are to be inserted through the boom on these other two (21–55, 50–150 MHz), add the boom diameter to each element

Table I. Spacing and Dimensions for Log Periodic VHF Antennas.

	21–55 MHz Array			50–150 MHz Array			140–450 MHz Array		
Element	Length, ft	Dia, in.	Spacing, ft	Length, ft	Dia, in.	Spacing, ft	Length, ft	Dia, in.	Spacing, ft
1	12.240	1.50	3.444	5.256	1.00	2.066	1.755	0.25	0.738
2	11.190	1.25	3.099	4.739	1.00	1.860	1.570	0.25	0.664
3	10.083	1.25	2.789	4.274	1.00	1.674	1.304	0.25	0.598
4	9.087	1.25	2.510	3.856	0.75	1.506	1.255	0.25	0.538
5	8.190	1.25	2.259	3.479	0.75	1.356	1.120	0.25	0.484
6	7.383	1.00	2.033	3.140	0.75	1.220	.999	0.25	0.436
7	6.657	1.00	1.830	2.835	0.75	1.098	.890	0.25	0.392
8	6.003	0.75	1.647	2.561	0.50	0.988	.792	0.25	0.353
9	5.414	0.75	1.482	2.313	0.50	0.889	.704	0.25	0.318
10	4.885	0.75	1.334	2.091	0.50	0.800	.624	0.25	0.286
11	4.409	0.75	1.200	1.891	0.50	0.720	.553	0.25	0.257
12	3.980	0.50	1.080	1.711	0.375	0.648	.489	0.25	0.231
13	3.593	0.50	0.000	1.549	0.375	0.584	.431	0.25	0.208
14				1.403	0.375	0.525	.378	0.25	0.187
15				1.272	0.375	0.000	.332	0.25	0.169
16							.290	0.25	0.000
Boom	25.0	2.0	0.5	16.17	1.5	0.5	5.98	1.5	0.5

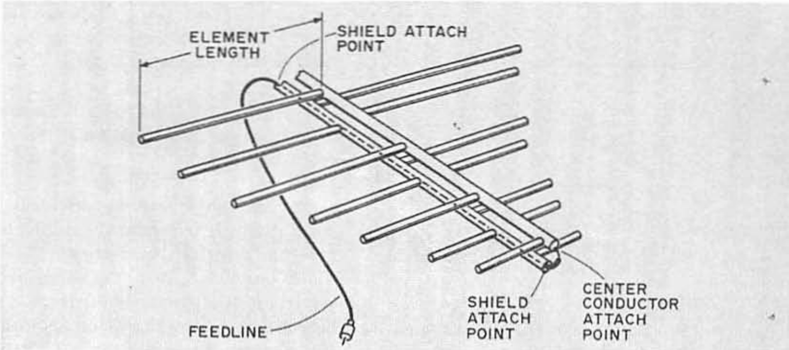


Fig. 1. Typical log periodic antenna. Note that the bottom is fed from the coax shield while the top boom is fed from the center conductor.

length shown before cutting the elements.

Two booms must be constructed for each antenna as shown in the isometric view of Fig. 1. Also remember, in supporting a log periodic antenna from a metal mast, the two booms must have a dielectric spacing from the mast of at least twice the boom-to-boom spacing; otherwise you will introduce discontinuities into the feed system.

Feedline insertion and connection are shown in Fig. 1.

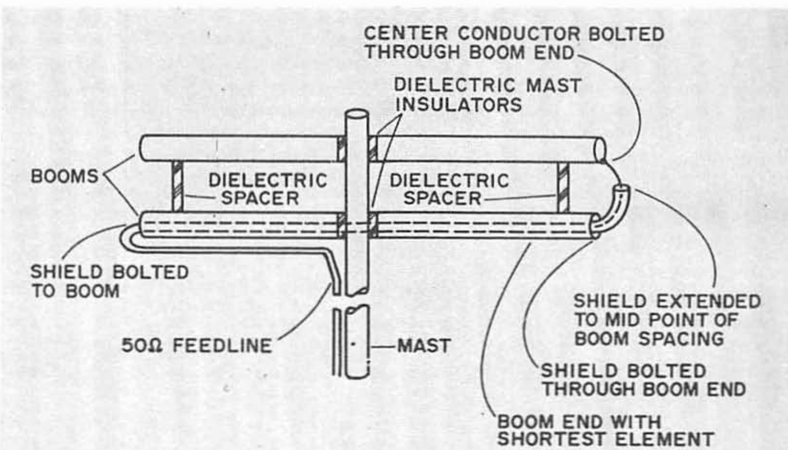


Fig. 2. Feeding the log periodic is relatively simple. Just remove the outer plastic jacket from feedline for the entire length of the boom, so that the coax shield is permitted to short itself inside the boom as well as the solid electrical connections at each end of the boom.

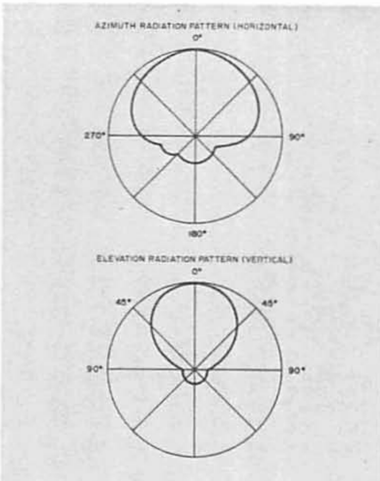


Fig. 3. Typical log periodic antenna patterns.

Notes

Any change in the listed boom diameters will necessitate a change in the boom-to-boom spacing in order to maintain the feed impedance at 50Ω.

The location of the support mast is not critical; ideally, it should be at the array's center of gravity.

The antennas may be oriented either horizontally or vertically, depending on the type of polarization desired. The horizontal beamwidth of a typical log periodic antenna is approximately 60 degrees, while the vertical beamwidth is on the order of 100 degrees. These are the −3 dB points shown in Fig. 3.

. . . W3DUQ ■

Oscillator & Infinite Attenuator for Tuning Receivers

One of the most useful test-equipment gadgets the homebrewer can build is a signal generator. The one described here is of commercial quality and it can be completely contained inside a waveguide. Positioning, by sliding along the waveguide, provides a variable-strength stable signal of one millivolt, one microvolt, one nanovolt, or less, dropping down gradually to a true zero. It does this in a perfectly smooth fashion without steps or jumps so that every fraction of a decibel in lower noise figure shows immediately on the slide dial. What's more, the slide can be calibrated so that FM'ers can use the device for directly measuring receiver sensitivity in tenths of a microvolt.

In building a 6 meter receiver recently for maximum absolute sensitivity we naturally had to check especially on the first-stage rf transistor and circuit for minimum noise figure. (For this type of work you *must* have a signal generator capable of being attenuated out of sight with any receiver you can buy for any money.) The usual generators on the market under $100 do not do this. And many of the very expensive generators get so leaky that they have to be used 200 ft from the receiver. At any rate, the generator described here can be made up quickly and at low cost, and it *is* stable, reliable, and infinitely variable.

Waveguide

The only possible difficulty might be in obtaining the piece of waveguide needed. The piece we used is 4¼ in. wide by 2 1/8 in. high, and is 24 in. long. If you have a choice, get a piece a little longer. You could make up this item out of brass or copper if you had to, because in this case it is not used to *carry* energy but to *attenuate* it, so the worse you make it the better!

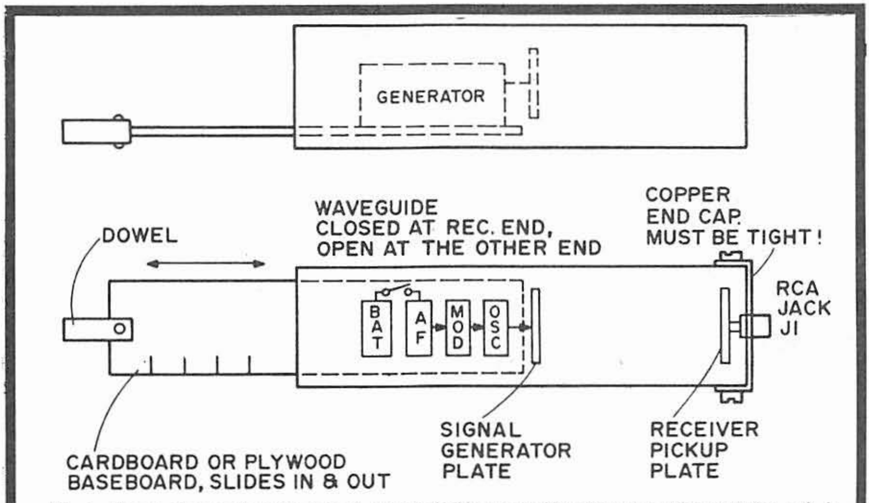


Fig. 1. Sketch shows plan-view layout of unit inside waveguide attenuator. The oscillator unit is mounted on a flat wood or cardboard strip that can be calibrated to give accurate indications of output signal.

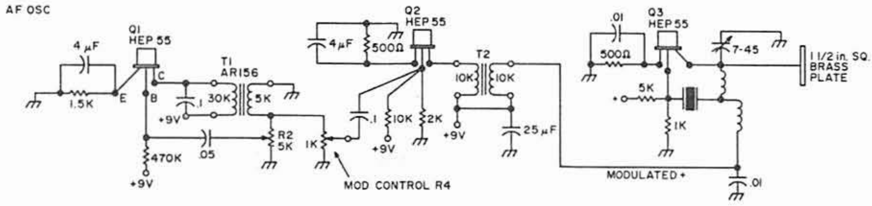


Fig. 2. Schematic of generator. This entire assembly about 3 x 4 in. including small 9V battery and switch must be entirely inside the waveguide. No wire or metal of any kind can be brought outside.

The waveguide *must not* have any holes in it and should be reasonably smooth inside; otherwise your dial would not read smoothly in attenuation. You *could* use copper or aluminum drain pipe, although we have not tried them yet. Working directly on the rf, this attenuator is good for any kind of modulation, including SSB, FM, pulse, or what have you.

Construction

Figure 1 shows the basic idea. When the signal generator plate is close to the receiver pickup plate, you can get about 100 mV of signal into the receiver, and it is handy for checking diode receivers. When the two plates are about 8 in. apart, the signal is just detectable on a good receiver. Additional spacing between plates amounts to "waveguide beyond cutoff." I do not believe that there is any receiver in the world that can pick up the signal much beyond the 8¾ in. point.

Pretty soon in your receiver "peaking" work you get to that signal that may be but a tenth of a microvolt or so, and you begin dreaming about cryogenic front ends, masers, and such. As mentioned, every fraction of a decibel lower in noise figure, every improvement in sensitivity comes out rigorously and relentlessly on that slide dial. You can easily check which of your low-noise transistors is really low, whether that MOSFET will do a better or worse job for you, and in which circuit.

As you go up in frequency you may have to make smaller and smaller oscillators in order to fit in smaller waveguides to get the cutoff effect.

Circuit

A crystal oscillator, an af oscillator, and a simple class A modulator do an excellent job to start with. Figure 2 shows the present unit as used on 6 meters. It must be stressed again that no wire or other piece of metal may be allowed to reach the outside from this assembly.

Audio

A controlled-feedback transformer-coupled af oscillator does a good job in furnishing a sine wave. A Motorola HEP55 is used for the oscillator, with feedback to the base from the collector through transformer T1, controlled by resistor R2. Audio output is taken off the 5 kΩ winding of T1, is fed through R4 the modulation control, and then to the base of af modulator Q2. Transistor Q2 is set up for low-power class A operation because not much modulation is needed for the signal generator. Transformer T2 is an old 5W unit from "tube-type portable" days. The secondary of T2 feeds a modulated +9V signal to Q3, the crystal-controlled 50 MHz oscillator.

This rf oscillator is a negative-feedback job with phase reversal in the crystal. A 1½ in. square plate is tied onto the collector, radiating energy to the receiver pickup plate facing it inside the waveguide. This energy is rapidly attenuated as you move the plates apart, and should be impossible to detect after some 9 or 10 in. of separation.

Once again, do *not* bring any wires or any other metal or conductor out from the

oscillator assembly. If you want an outside controlled switch or other control, bring it out as a wooden dowel handle.

Tune everything up outside the waveguide on the bench; when you're satisfied, plug your best 6 meter receiver into J1, push the oscillator plank along the waveguide (or rather I should say pull it along) away from J1. You'll get a surprise! Hope this helps you with your low-noise receiver work.

. . . K1CLL ■

Add-On Neutralization

Ever build what you thought was going to be "just a simple straightforward amplifier" when you found you needed a little more gain, a little more isolation, a little more power, or all three and then find you can't eliminate self-oscillation?

Now what do the books say? Some of the "best" are worse than useless! Listen to this one. "Any amplifier will oscillate if sufficient energy having the same frequency and the same phase as the grid voltage is fed back from the plate circuit to the grid circuit."

If you think a little about the energy fed from a plate to a grid by the internal Cgp of the tube, you will see that this is in *phase* or nearly so. And this is not the proper phase for a vacuum tube oscillator, which as I'm sure. you know, should be *out of phase*. Grid going positive, plate going negative, etc. Actually a tube which is self-oscillating does so in spite of the phase effect. There is some phase shift in the small Cgp and the frequency of the plate and grid circuits are *not* exactly in tune either. Remember how a crystal oscillator tunes "up one side" and then jumps out of oscillation?

Now the funny thing is that proper neutralizing energy which is fed back by the neutralizing circuit is in the correct phase for oscillation! That is, 180 degrees out of phase. Of course, if you will look back at the previous paragraph you will see that the nuisance feedback from plate to grid through the GP

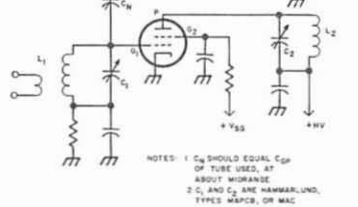


Fig. 1. "Outboard" neutralizing circuit.

capacity is in phase, so that neutralizing energy would have to be out of phase to cancel it.

Let's take the tube I used above, the 5763. Here's a good tube. Used in loads of circuits. Does anyone tell you whether or not it has to be neutralized? No Sir. I haven't found a word on that yet. You look up the Cgp and find that it is listed as only .3 (three tenths) of one micro-micro-farad. That's pretty small isn't it? Or is it? Will it self oscillate? Should you first build a split tank with a neutralizing capacitor over to the grid? You'd think the handbookers suddenly ran out of ink! Let's look at a tube which we know is generally not neutralized. The 6BA6, for example. Ah hah! The Cgp is only .0035 max. Thirty-five ten thousandths of a micro-micro-farad. That's real small!

The 807 has a Cgp of .2 mmf which is where a lot of that tube's instability comes from. In the 2C39, a triode, but generally used in grounded grid circuits, with the cathode the active element that could generate trouble, we find that the Ckp (note, plate to *cathode*) is .035 max. Not quite as good as the 6BA6 but a good deal better than a lot of other transmitting tubes.

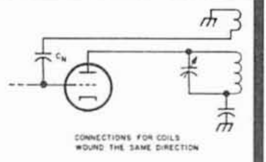
So, how do you know when to build a neutralizing circuit in or not? You don't really. The books don't tell you. I generally figure that when the Cgp is in two decimal places or less, like .05, you *may* not need to neutralize. If it's in the tenths, like .2 or more, you probably will. You can also see that due to the natural-born increase in power through a small capcitor with increasing frequency where this will lead you to on VHF or UHF.

Note that the 6AK5 has a Cgp of .02, quite a bit more than the 6BA6. The 6AK5 was found in lots of places where perhaps it should not have been, but all's fair in love and war, and that was a war tube.

One of my favorite transmitting tubes is the quick-heating 7 watter, the 5618. However, its Cgp is .24 so I have always had to neutralize it.

So by now you get the general idea, and if you did build that amplifier without the usual neutralizing tank circuit, or can't make up your mind, or just plain don't want to,

Fig. 2



never mind. We are about to show you how to add it on later as an after thought.

Actually, this neutralizing circuit works even with a high-gain grounded cathode triode on two meters.

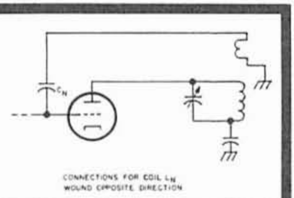
So far it has worked every time. Just build up a good grid circuit, use good shielding, a good plate circuit, fire it up, watch your grid drive go as you tune through resonance with the plate circuit, and then go to work and neutralize it.

Just put a few turns of reverse phase winding (Ln) in or around L2 and couple it over to the grid, through the shield, with Cn for amplitude adjustment. Remember that this reverse phase is just what the doctor ordered to make an oscillator and can be done in more ways than one. If you wind Ln in the same direction, that is clock-wise, or counter-clockwise, as L2 is wound, use the opposite end from the plate to get the out of phase energy. See Fig. 2.

If you wind it in the opposite direction from the plate coil L2, use the same end to get the out of phase energy. See Fig. 3.

There's a real fancy deal going on here in fundamental magnetic coupling like left and right hand snail shells.

Fig. 3

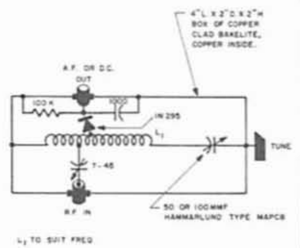


Some smart transformer people can wiggle three fingers so as to point in three different directions at once, and call this the magnetic rule of thumb. Never mind, just remember "with a tube oscillator coil, put the plate on one end and the grid on the other."

Also, you can put Ln almost anywhere and it will work. On the end of L2, interleaved, inside L2, or outside.

To adjust Cn, do like the books say. We use a tuned circuit detector. It helps to be sure just what frequency you *are* neutralizing. Plug the detector right into the output jack, but, unless you have lots of spare diodes, don't turn on the amplifier plate and screen supply!

Fig. 4. Tuned detector.



It is really helpful to watch that meter (the diode meter) go down to, or near, zero, in the neutralizing null. It kind of restores your confidence in the fact that, if the theory you're using is correct and if your circuit is built right, it is a law of nature that it must work! And, I almost-forgot, you can use that same detector, with a little transistor amplifier and a pair of "Hi-Fi" padded earphones, the kind with the real big large pads on them, to listen to your own modulation. But don't plug it into the rf output with the power on! Just have it nearby! And be sure it's the *diode* you're listening to. The af amplifier can pick up rf and rectify it plenty loud, but you won't like that modulation. Another reason for the tuned detector. It works FB for almost any purpose. It also goes to 432, with a strap for L1. Also ditto for a 1215-1296 megacycles detector.

. . . K1CLL

Panoramic Reception Adapter

The serious VHF-UHF operator is interested in what's going on over a relatively large frequency spectrum. A panoramic receiver of some type can be a great help.

Usually the adapter scans the *if* of the receiver and displays what is present in the *if* passband on the face of a cathode ray tube. As the receiver is tuned in this case, the display moves, with the signal heard in the speaker being displayed in the center of the CRT. However, the range of frequencies seen on the screen at any one time is about 100 kc or less due to the selectivity of the receiver *if* system and/or the front end selectivity. If the receiver is left tuned to one spot on the VHF band, only 50 kc each side of that point is visible on the CRT. That's not much range compared to the limits of any VHF or UHF band.

There are other methods of obtaining panoramic displays and the following is a description of a usable unit. This simple gadget will allow a standard oscilloscope to be used as the screen. In addition it will allow a much larger portion of the band to be observed at one time, in fact *all* of the band in some cases. The amount of band viewed is variable and one "pip" or signal can be centered and "blown up" to check modulation and to be heard in the receiver speaker. In this case the spectrum viewed is just the band width of the receiver.

A dual triode is connected as a sawtooth or sweep generator just like the one in an oscilloscope. The output of this is fed thru a level control to the horizontal input of a regular oscilloscope. This control varies the width of the display and doesn't affect the frequency range. This same sawtooth waveform is also fed thru another level control to a voltage variable capacitor or varicap, diode. This diode is in the frequency determining circuit of a triode rf oscillator. This local oscillator is set up on the same frequency as the oscillator in the receiver or converter used. When the sawtooth voltage gets to the varicap, the oscillator changes frequency in step with the spot going across the scope tube face. Meanwhile the vertical circuit in the scope is looking at the receiver *if* output and when a signal appears it causes the spot to be deflected vertically. Thus, for each signal, a "pip" appears on the scope base line to indicate a signal, the frequency of this signal can be determined by its relative position from left to right. Since the sweep for the spot and the local oscillator are from the same source and "in step" the pips will remain stationary. The level control in the varicap circuit becomes the band width control.

The pip can be *if* voltage or this voltage can be detected by a diode. **Fig. 1** shows the two methods and their resultant displays. In the case of looking at the *if* directly, the vertical amplifiers in the scope have to be capable of handling the *if* frequency. Many scopes will show up to 5 megacycles.

When the spot on the scope finishes its relatively slow trip from left to right across the screen, it has to come back to the starting place. Due to the rapid fall off of the sawtooth voltage from its peak value, this journey is made in much less time. The result is a dim line across the scope from right to left. Signals present in the vertical circuits at this time will be seen as dim "ghost" images, greatly widened because of the speed of the retrace. If the electron beam in the CRT can be cut off during this period, this retrace can be eliminated. If this is desired, a triode grounded grid circuit is included to feed a pulse from the cathode of the sawtooth oscillator to the CRT cathode in such a way as to bias it to cutoff at the right time. If the scope has a "Z" axis input connection this probably could be used. In the RCA WO33A used at this

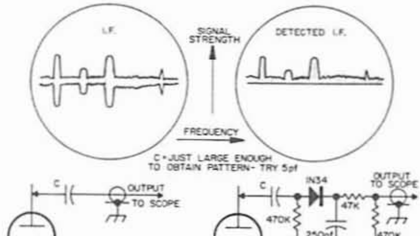


Fig. 1. Vertical scope connections to receiver.

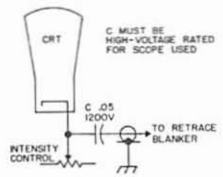


Fig. 2. Retrace blanking (optional).

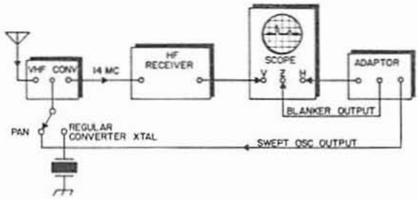


Fig. 4. Interconnection block diagram.

QTH a coupling capacitor was added in the scope from the cathode of the CRT to a phono socket on the front panel. The retrace blanking pulse is fed in here and puts a positive pulse on the CRT cathode at the right time to cut off the spot. This cathode has about 650 volts negative and the plate of the blanker a couple hundred positive, so better use a good pair of .1 µf at 600 volts in series or something better for the coupling capacitor.

The other half of the blanker is used as a buffer for the oscillator to isolate it from the receiver circuits. This also makes it possible to "swamp" the output of the adapter to keep from overdriving the receiver circuits.

Of course you will use small coax or shielded cable for all interconnections between scope, receiver and adapter. Parts layout is not critical, but keep lead lengths down and mount the RF parts solidly so calibration will hold.

The RF oscillator in the unit can be almost any type as long as it is capable of covering the desired frequency range. Extreme stability is not needed as a small frequency shift will not be noticeable if a large portion of the band is being scanned. With a given circuit, a high ratio of inductance to capacitance will give the most frequency change with a given capacity change. A limit to this is reached when the "Q" of the circuit becomes too low to allow oscillation. Some types of diodes will have a lower "Q" and may be the limiting factor on the frequency range covered.

In the circuit shown, a regular power rectifier diode (silicon) is used as the varicap. One with a 400 to 750 volt peak inverse rating is adequate. Individual units will have somewhat different characteristics as to "Q", dc bias needed for a given capacity and capacity range available. Almost any will work but try a few if available and see if one of them might be better than the rest.

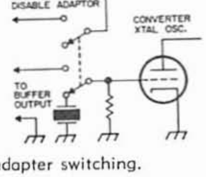


Fig. 3. Panadapter switching.

A regular varicap or varactor may be used but be careful not to exceed the piv rating. The circuit shown will exceed these ratings and should be modified at the "X" points in the high side of the diode bias control and the band width control. A suitable resistor may be inserted at these points to limit the voltage the controls may place across the diode. These resistors may run to several megohms. Leave out the diode until you have installed the resistors by trial and then run the controls all the way up and measure the dc bias with a VTVM and the sweep with your scope and be sure it isn't too much for the varactor you choose. This is not a problem with the power diodes used in the circuit as shown. More frequency range may be obtained with the varactors but other problems appear. The RF voltage at the grid can override the small bias used. A 100 pf at 4 volt diode tapped down on the coil between cathode and ground thru a 250 pf capacitor with dc bias of about 4 volts (using 10 meg resistors in the "X" positions) will cover all of 2 meters easily when used as shown with a 2 meter convertor to a 14 mc receiver. As more band is covered it becomes more likely to get a spurious pip somewhere along the base line. Actually the power diodes are easier to work with in tube circuits and give plenty of frequency range. The low voltage high capacity diodes are ideal for use in transistor circuits. Those of you who believe the little rascals are here to stay could convert the circuit to a transistor operation.

The frequency range of the oscillator will depend on the receiver or convertor it is to be used with. The injection may be made into the crystal socket of most converters and in this case it may be one half of the crystal operating frequency. An example is the much used 2 meter converter working into a 14 to 18 mc receiver. The crystal in these converters is usually marked 43.33 mc. The output of the crystal oscillator is tripled to 130 mc and the result of mixing this with 144 to 148 mc is

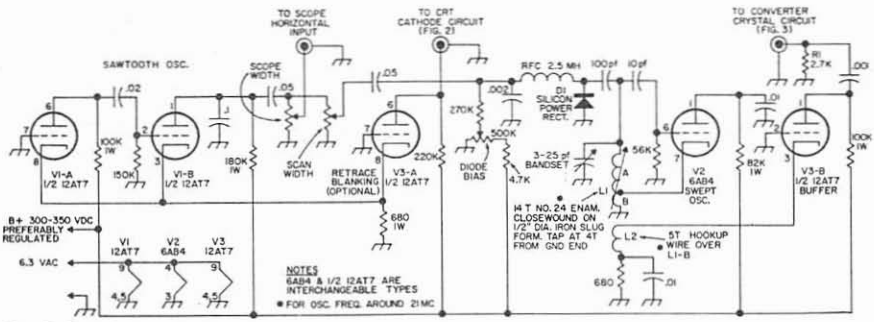


Fig. 5. Panadapter circuit.

the 14 to 18 mc you feed into your receiver. So if a sweep frequency of 21.66 to 22.33 mc is put in where the crystal was the result is a 144 to 148 mc sweep which comes out on 14 mc. Tune your receiver to 14 mc, connect up the scope and adapter and you will be looking at 144 to 148 on the CRT screen. Of course in this case you are getting 6 times multiplication of the sweep range by the multiplier chain in the converter. Resistor R1 across the output of the buffer is to keep the crystal oscillator from generating spurious frequencies due to overdrive. This resistor looks pretty low but even less can be used. If too much oscillator voltage gets across the large resistor in the crystal oscillator grid circuit the tube becomes a good harmonic generator and lots of strong "birdies" appear on the screen.

Another place to insert the sweep oscillator output is the mixer stage in the hf receiver. In this case not so much range is available because of the front end selectivity of the receiver. However from 14 to 14.5 can be covered with most receivers. This would give you 500 kc of any VHF band depending on which converter you switched to. Also coverage of twenty meters which is rumored to be still in operation.

In any case the unit should be arranged so it can be switched in and the regular tuning oscillator or crystal out and vice versa, with just the flick of one switch. The oscillator should be disabled when normal tuning is used to keep down any odd birdies that might appear.

A few things to keep in mind when building the unit to use with a particular receiving setup: The more range you cover, the less distance between pips and the less you can tell of their nature. If you put a fairly good dial on the bandset variable capacitor in the oscillator you can center a pip and keep it centered while you reduce the sweep to zero and look at that signal alone and hear it in the speaker. On a dead VHF or UHF band a signal coming on will cause a low frequency note in the receiver speaker. Vary avc, bfo and volume settings for best results. If different selectivities are available on the receiver see which works best. If noise pulses from a 60 cycle source stand still on the screen, change the .1 μf capacitor or the 180 k resistor in the sawtooth oscillator slightly so it will not sync with the noise. This will make it easier to distinguish between signals and power line noise. Turn the rf gain down so that noise is just visible on the base line. You can spot check with your own transmitter or exciter to determine the frequency range covered. Be sure and compare your ability to detect weak signals with the scope to results you get by listening to the speaker and manual tuning with the bfo on.

. . . W5NPD

VHF Frequency Calibrator

If You've ever listened to the "VHF Nut Net" on 3815 kHz, Mondays at 0500 GMT, you've heard the elaborate scheduling between stations for long-haul VHF QSO's. The current schedules are mostly on two meters, near the bottom end of the band, via meteor-bursts. The frequencies quoted are usually given in kHz above 144 MHz, and these serious VHF'ers *mean* it when they say 144.013 MHz.

While most serious VHF'ers *can* be on at least one two-meter frequency to a tolerance of ± 100 Hz, there are occasional apparent errors. These show up in the comments on the "VHF Nut Net" like: "I listened for you on 144.006 MHz last Wednesday, but didn't copy. I did hear a few 'pings' up at 144.008 MHz, though. That couldn't have been you, could it?"

To assure oneself of being on some arbitrary VHF frequency to within 100 Hz is no easy task. If we could operate "right on" 144.000 MHz, it wouldn't be so hard to check; but that isn't the usual case. Rather, we are usually required to use a VHF frequency that isn't the harmonic of any of the usual standard frequency sources.

There are a number of ways of making frequency measurements of VHF signals, and they all have limitations. Basically, the problem is that we are trying to make a very precise measurement; 100 Hz in 144,000,000 is better than one part in a million. To see why stations are not always on frequency, see the frequency versus temperature curve of a typical 8 MHz AT cut crystal in **Fig. 1.** Notice that over the range from 10° C to 40° C, a reasonable "shack" temperature range, the frequency of the crystal can vary about .0015%. This much variation is over 2 kHz, when multiplied up to 144 MHz.

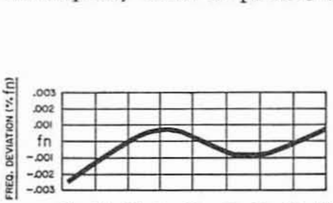


Fig. 1. Typical temperature curve of an 8 MHz AT-cut crystal. Note that the crystal frequency varies up to 0.0015% from 10° C to 40° C, a normal shack temperature range.

A logical extension of the principles used to calibrate high-frequency receivers has been used on 144, 220, and 432 MHz. This is simply the use of a very fast switch in the harmonic generator section of a 1 MHz calibrator. With a tunnel diode, or snap diode, doing the switching, useful harmonics spaced 1 MHz apart can indeed be generated through 432 MHz. This method is really the brute-force approach, since the harmonics we are interested in, in this case, are the 431st, 432nd, and 433rd. Harmonics spaced at 100 kHz intervals could, also, be generated in the same way, but then the harmonics of interest would be the 4310th through the 4330th!

As most hams know from experience, harmonic amplitude decreases as we look for successively higher ones. This is predicted in detail by Fourier Analysis* of nonsinusoidal waveforms. Several nonsinusoidal waveforms are shown in **Fig. 2,** with their Fourier series to illustrate this. Note that the harmonics of these two different waveforms drop off at different rates with frequency. However, both do drop off as $1/n$ or faster (where n is the harmonic number). Therefore, in a 100 kHz interval calibrator for two-meter use, we can expect to have *less than* 1/1440th of the signal for calibration at 144 MHz if the rate of fall off of the Fourier series is $1/n$. If the fall off rate were $1/n^2$, we would have only $1/(1440)^2$th. A one volt 100 kHz signal, then, can theoretically produce a 1440th harmonic of about 0.5 μv, if the series falls off as $1/n^2$. Extension to

*For those of you are so inclined, the Fourier series for the square wave in Fig. 2 is $e = A_1 [\sin(\omega t) + 1/3 \sin(3\omega t) + 1/5 \sin(5\omega t) + 1/7 \sin(7\omega t + \ldots. 1/n \sin(n\omega t)]$. The Fourier series of the triangular wave in Fig 2 is $e = A_2 [\sin(\omega t) - 1/9 \sin(3\omega t) + 1/25 \sin(5\omega t) - 1/49 \sin(7\omega t) + \ldots. - 1/n^2 \sin(n\omega t)]$. From the last term in these equations it can be seen that the harmonics of the square wave fall off at the rate of $1/n$, while the triangular wave harmonics fall of at $1/n^2$.

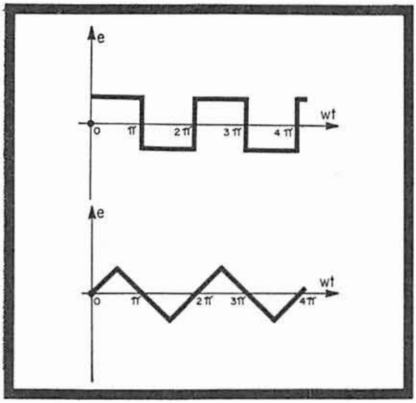


Fig. 2. Two nonsinusoidal waveforms which may be used for harmonic generation. The Fourier series of the square wave indicates that harmonics fall off at the rate of $1/n$, where n is the harmonic number. The harmonics of the triangular wave fall off at the rate of $1/n^2$.*

10 kHz-spaced marks will further reduce harmonic levels by a factor of between 10 and 100 (depending on whether the fall off rate is $1/n$ or $1/n^2$ respectively). To top all this off, it can be rather interesting to determine "which picket is which" in this "picket-fence" of harmonics that we've succeeded in generating.

The VHF calibrator presented here attempts to solve the fundamental problems of the brute force approach by applying techniques that are used in modern frequency-synthesis. The circuitry is admittedly more complex, but the use of integrated circuits helps considerably to ease the construction job as well as to reduce the cost. This two-meter calibrator offers a choice of calibration modes: 144 MHz alone, 144 MHz ± 1 MHz, 144 MHz ± 100 kHz, or 144 MHz ± 10 kHz. The mode-switching allows one to go from a rough 1 MHz interval frequency check to a 100 kHz interval check, and finally, to a 10 kHz interval check.

The system is described in **Fig. 3.** Note that the 1 MHz crystal standard is both multiplied-up *and* divided-down. We produce, by means of a rather ordinary frequency multiplier chain, a clean 144 MHz CW signal that is exactly 144 times the frequency of the 1 MHz standard. This 144 MHz signal is then modulated by a rectangular wave at 1 MHz, 100 kHz, or 10 kHz; this modulation produces the desired marks. The main difference between this method and the brute-force approach is that our markers now fall off in amplitude as we move away from 144 MHz (in either direction in frequency). Because we are now only interested in harmonics of the modulation frequency that are of relatively low order,

*Fourier analysis is a mathematical method whereby a series of sine and cosine terms of the integral multiples of frequency are used in evaluating the harmonics of complex waveforms.

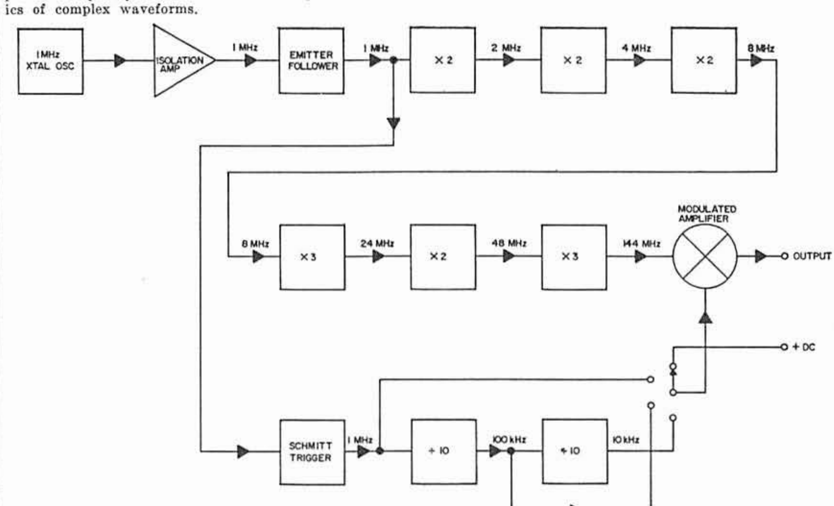


Fig. 3. Block diagram of the VHF man's calibrator.

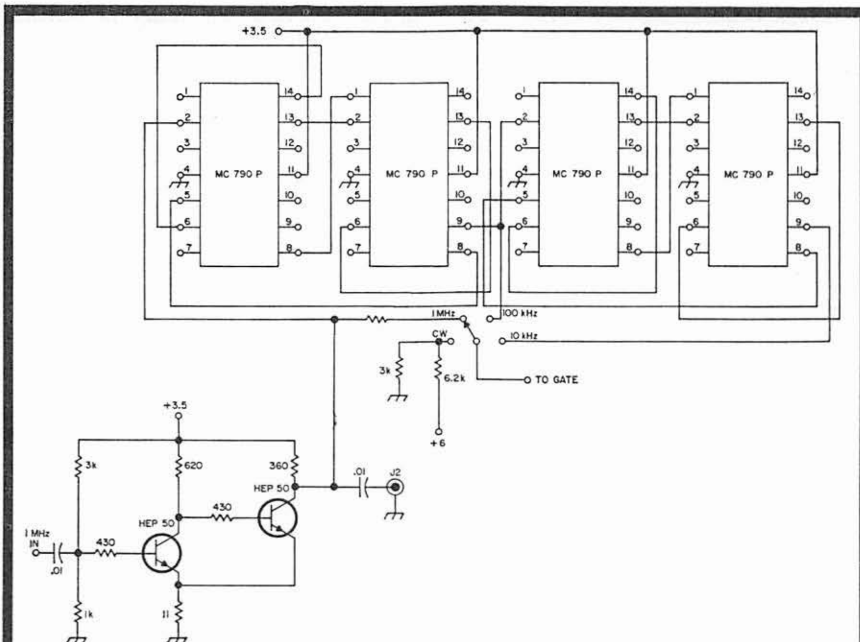


Fig. 4. Divider section uses integrated circuits to generate 10 kHz and 100 kHz marker signals from a 1 MHz crystal. The unmarked resistor in the 1 MHz should not be there—short it out.

the rectangular wave does not have to have a nanosecond rise or fall time. The "modulation" is not of the linear sort that hams usually encounter, since the rectangular wave essentially turns the signal off and on.

The circuit diagram is shown in **Fig. 4.** Note the use of digital integrated circuits. The internal circuitry of the individual IC's isn't shown since it would make **Fig. 4** vastly more complex. The Motorola HEP line of semiconductors is used for the most part, except for the four dual J-K flip flops. These J-K flip-flops are wired to divide 1 MHz by two decades. The MC790P flip-flops (Motorola) are members of a logic family called RTL (Resistor-Transistor-Logic) which is inherently slower than MECL (Emitter-Coupled Logic), to which the HEP digital integrated circuits belong.

If you wish to use HEP 558 J-K flip-flops to replace the MC790P's, the circuit changes of **Fig. 6** should be used. Since the HEP digital IC's are designed for +6 volts, a much simpler power-supply and regulator are used.

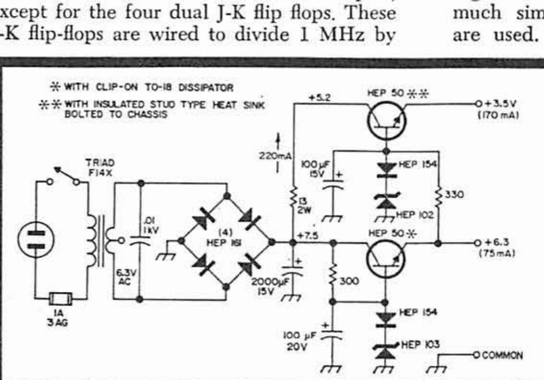


Fig. 5. Power supply section for use with the integrated circuit divider of Fig. 4.

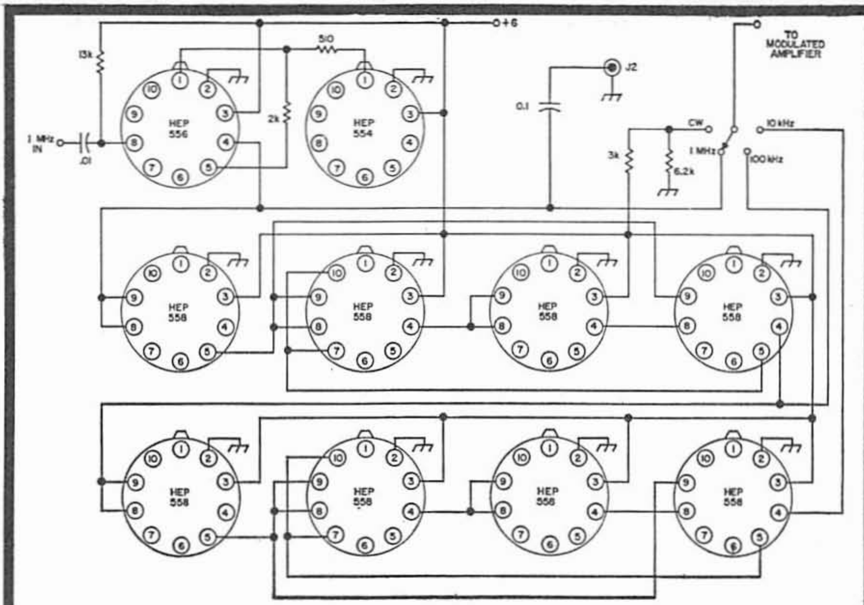


Fig. 6. Divider circuitry using HEP 558 J-K flip-flops to replace the MC790P RTL IC's which are inherently slower.

The crystal oscillator sections, in both versions, use an FET as a Miller oscillator. The Miller oscillator was used here because the DC9AJ crystal (1 MHz) was designed for that type of circuit, and has one side of the crystal grounded to the crystal can. Following the crystal oscillator is another FET, operating as a Class-A isolation stage. The isolation amplifier feeds an emitter-follower that in turn drives both the "count-down" and the "multiply-up" portions of the circuitry. The low output impedance of the emitter follower is needed primarily to drive the first multiplier.

The multiplier chain is conventional in its design—x2, x2, x2, x3, x2, x3—a total multiplication of 144. In the four lowest frequency stages, double-tuned interstage coupling is used. This double-tuning is to prevent the possibility of any 1 MHz, 2 MHz, 4 MHz, or 8 MHz side-frequencies from appearing around our 144 MHz signal when S_2 is in the CW position. All the multipliers are PNP mesa transistors, operated "up-side-down" so that the +6 volt supply feeds their emitters. The modulated amplifier is a grounded-base stage, with the base as the modulation-control element.

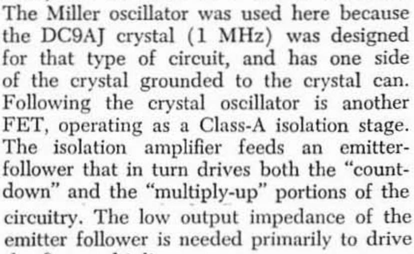


Fig. 7. Power supply for the HEP integrated circuit divider of Fig. 6.

Tuning of the multiplier section is easily accomplished with a grid-dip meter used as an absorption frequency meter. The divider section can be checked by loosely coupling the output of S_2 to a high-frequency receiver and listening for the various harmonics, say at 80 meters. If the divider section is wired correctly, it will put out the right frequencies.

Checking the divider section with a high-frequency receiver, points out a potential problem. If the frequencies generated by the divider section are allowed to get into the receiver that is used as an *if* for your VHF converter, confusion will reign. The overall shielding of the calibrator, the general supply lead decoupling, and the VHF bandpass nature of the modulated amplifier are ade-

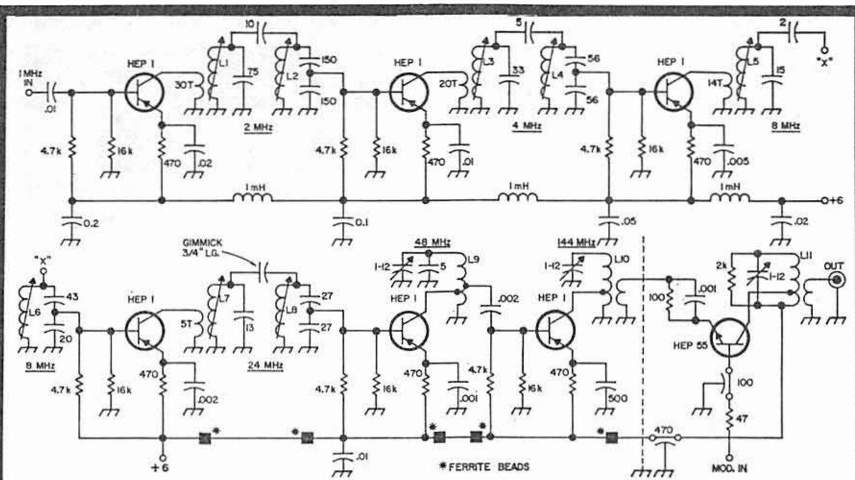


Fig. 8. The times 144 frequency multipler. A crystal controlled input at 1 MHz provides an output at 144 MHz. Coil information for this circuit is given in Table 1.

quate to prevent such a problem in the units shown.

However, 1 MHz harmonics *can be* purposely coupled out (from the Schmitt Trigger) via J_2. These 1 MHz harmonics are used to beat with WWV on 5, 10, 15, or 20 MHz (in a high frequency receiver), for calibrating the 1 MHz crystal oscillator.

Operation of the calibrator would then be as follows. Couple the 1 MHz harmonic output (J_2) to the receiver with a small (5 pF) capacitor. Tune in WWV on the *highest* frequency that provides satisfactory reception. Adjust C_1 (the 1 MHz crystal oscillator frequency control) for zero beat. Zero beat is best observed on the "S" meter of the receiver. This is because the low-cutoff frequency of the receiver audio amplifier won't pass near-zero beat notes for aural monitoring. Disconnecting the cable from J_2, the VHF output of the calibrator (J_3) is coupled to the VHF converter by means of a directional coupler and attenuator. The total decoupling between the calibrator and receiver should be about 50 dB. A temporary expedient for coupling the receiver to the calibrator may be used: a 6 to 12 inch piece of wire is simply connected to J_3 to radiate the calibrator output into a nearby antenna.

S_2 is first put in the "CW" position and 144 MHz found on the receiver. Then the switch is set to "1 MHz" and 144, 145, 146, 147, or 148 MHz found (which ever is closest to the desired operating frequency). Then we switch to "100 kHz", and finally to "10 kHz", selectively pinning down our frequency.

If desired, another decade could be added to the count-down circuits to give 1 kHz intervals. Also, another tripler could be added

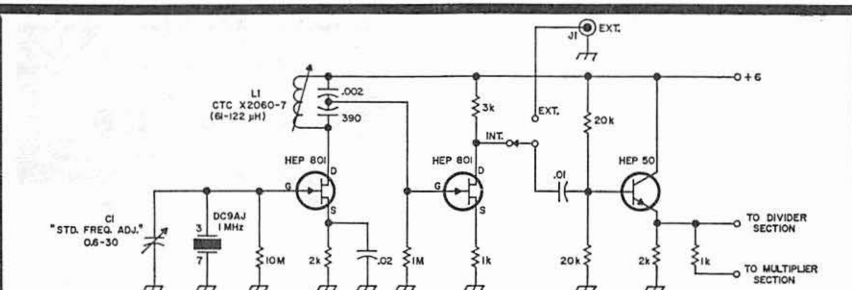


Fig. 9. One MHz oscillator-buffer section.

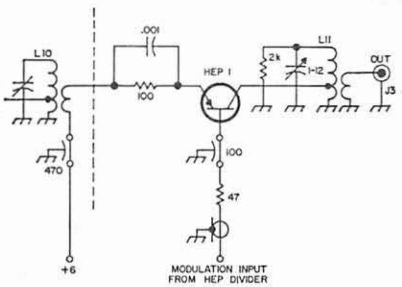


Fig. 10. Modulated amplifier for use with the HEP divider section. This circuit replaces the last HEP 55 stage in Fig. 9. when HEP IC's are used.

to the multiplier chain, making the calibrator useful at 432 MHz.

Another intriguing possibility is the use of WWVB (60 kHz) or WWVL (20 kHz) as a calibration signal. By using a divide-by-five circuit on the 100 kHz output of the first decade divider, a 20 kHz signal for comparison with WWVL is produced. By simply putting this 20 kHz rectangular wave (which is rich in third harmonic power) into a 60 kHz tuned amplifier, a 60 kHz signal is produced for WWVB comparison.

You might ask why we didn't divide 100 kHz by five and then 2 to obtain 10 kHz, allowing a 20 kHz pick-off after the divide-by-five section. That was not done because it produces a *symmetrical* 10 kHz square wave for calibrator use. This type of waveform has very small even-harmonic power.

Construction of both units was in modular form, with the individual modules enclosed

Table 1. Coils used in the times 144 frequency multiplier

- L1 = CTC (Cambion Thermionic Corporation) X2060-7 with 30 turns #28 on primary winding.
- L2 = CTC X2060-7
- L3 = CTC X2060-6 with 20 turns #28 on primary winding.
- L4 = CTC X2060-6
- L5 = CTC X2060-5 with 14 turns #28 on primary winding.
- L6 = CTC X2060-5
- L7 = CTC X2060-1 with 5 turns #28 on primary winding.
- L8. = CTC X2060-1
- L9 = 10 turns Airdux 416, collector tap at 2½ turns, base tap at 3 turns.
- L10 = 7½ turns #12, ¼" inside diameter. Collector tap at 3 turns. Secondary is 2 turns #20 solid insulated hookup wire.
- L11 = 7 turns #12, ¼" inside diameter. Collector tap at 2 turns. Secondary is 1½ turns #20 solid insulated hookup wire.

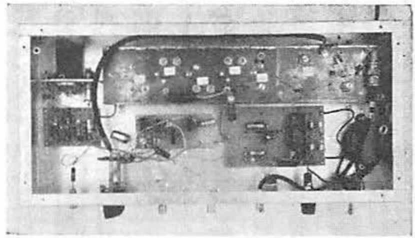


Fig. 11. Construction of the calibrator illustrated schematically in Fig. 4. Motorola MC790P dual RTL J-K flip-flops are used in the divider section.

in a 8 x 17 x 3 inch aluminum chassis which serves as a cabinet. **Figs.11** and **12** show the two calibrators built by the author.

The multiplier chain assembly (which also contains the 144 MHz modulated amplifier stage) is built from copper laminated board which is used in making etched circuits. This material is easily sheared, drilled, punched, reamed, and soldered. The bottom view of one of the multiplier chains is shown in **Fig. 13** and its top-plate template is shown in **Fig. 14.** Note in **Fig. 13** that alternate multiplier stages have their transistor cans inverted; this was necessary because of the coil-mounting positions. The coils were mounted on alternating sides of the "strip" to assure stability since there is no shielding between multipliers. There *is* a shield between the 48 MHz to 144 MHz tripler and the 144 MHz modulated amplifier stage, of course.

Except for the crystal oscillator, capacitor C, and inductor L_1, the crystal oscillator circuitry is built on a piece of Vector board (64AA18). The crystal, C_1 and L_1, are mounted next to the oscillator board on a metal bracket. The metal bracket is

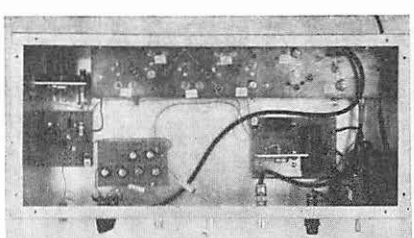


Fig. 12. VHF calibrator built with **HEP 558** J-K flip-flops in the divider section. This photograph shows the unit in early stages of construction, with only one decade of dividers in use. Later four more HEP 558's were added to provide a second decade.

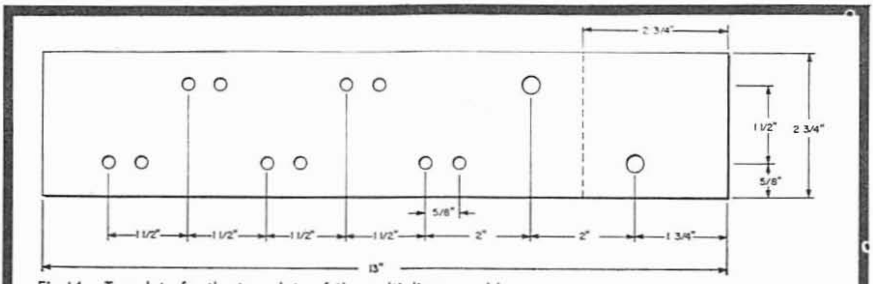


Fig. 14. Template for the top plate of the multiplier assembly.

positioned so that L_1 and C_1 may be adjusted through two holes in the rear of the cabinet.

The power supply is also built on Vector board except for the transformer and one of the regulator transistors in the dual-voltage version.

The divider units are also built on Vector board. Vector 64AA18 is used in the unit with the HEP IC's with holes in the board in which to mount epoxy HEP 451 sockets. The divider unit that uses MC790P type IC's is constructed from Vector 85G24EP because the hole-spacing is adaptable to the IC pin-spacing. Vector pins (T28) are used for this 85G24EP board, whereas Alden 651T terminals are used for the 64AA18 board.

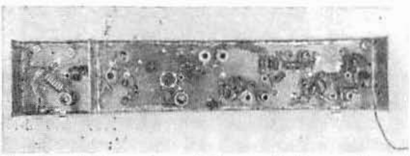


Fig. 13. Bottom view of the multiplier section of the VHF calibrator. A second tripler section could be added for use on 432 MHz.

The calibrators described above have proved very useful in two-meter frequency measurement, both in measuring meteor-scatter stations' frequencies and in accurately measuring MARS frequencies at 143.950 and 148.010 MHz. Though somewhat more complicated than most calibrators, either can be built in a few evenings of persistent fabrication.

. . . W6GXN

RF Noise Suppression

Probably one of the least understood problems with VHF mobile is *rf* noise suppression. After participating in, and listening to many conversations, it becomes apparent that a basic knowledge of the problem is lacking.

One of the most common complaints is that the converter or receiver is at fault because it picks up noise, or the antenna is at fault for the same reason. If the receiver and antenna are at all satisfactory, you *will* hear noise, for neither has intelligence to differentiate between the radio station to which you wish to listen and that being transmitted by the electrical system. True, most VHF receivers have some type of noise clipping which takes place either in the *if* section or second detector, or a blanker between the converter and receiver. It is also true that a narrow pass band in the *if* section will help; however, as most amateurs today are using commercial equipment, little can be done about this. Sometimes the location of the antenna will help, but these things in themselves will not cure all evils.

RF noise in mobile operation falls into two main categories. The first is conducted *rf* noise, and the second, radiated *rf* noise. Both types are quite broad banded. Conducted *rf* noise is that which is conducted along the electrical system of the car, and may originate from the alternator or generator, the voltage regulator, the points at the distributor, the windshield wiper motor, turn indicator flashers, etc.

The first step in conducted *rf* noise suppression is to remove the antenna from the receiver and short out the antenna jack. Turn the gain up and note the amount of inherent noise in the receiver (nothing can be done about this unless you want to rework the receiver). Start up the engine with the antenna jack still shorted. Rev the engine up and down. In most cases, you will hear alternator whine and distributor noise. Shut off the engine and start the windshield wiper. Increase and decrease speed. Shut off the wiper motor and start the turn indicator. Follow this through for any electrical device.

Now, for the conducted noise suppression: In some cars most of the electrical equipment conducted noise cannot be tolerated. In others, perhaps only two or three areas will require suppression. A great deal depends on the individual operator. In all conducted noise suppression, mount the suppressor as close to the offending equipment as possible. The reason for this is that as noise is being conducted along the electrical system, it can start radiating, and become an additional problem.

For alternator or generator suppression, there are two main types of suppressors. One is the tuned parallel trap, consisting of a coil and variable capacitor. This is connected in series with the lead from the alternator (as closely as possible). Of course this trap must be able to resonate at the desired listening frequency.

Now, with the antenna jack still shorted, and the audio gain well advanced, tune the trap for minimum noise. The second method, and my choice, is to install a feedthrough capacitor as close as possible to the alternator.

Perhaps a word at this time about feedthrough capacitors would not be amiss. A feedthrough, as its name implies, is one where the conductor, or lead, goes through the capacitor. The foil making up the capacitance is wound around this lead. The other lead of the capacitor is usually the metal case. From this it can be seen that inductive reactance is held at a minimum, and that any noise present on the line is forced to take this path. Be sure to scrape the metal clean in mounting capacitors. Do not use a wire ground lead, as the inductive reactance in the lead may defeat the purpose of the capacitor. As to the value of the capacitor necessary, this will depend on the amount of suppression needed.

There are several companies who publish charts showing current capacity, frequency and suppression in db, and the necessary capacitance value together with the types of mechanical mounts. The current spoken about here refers to the amount of current the lead can pass. For example, if your alternator can produce 30 amperes, a 30-

ampere type capacitor is needed. If the alternator can produce 60 amperes, a 60-ampere capacitor is needed. I was unable to acquire this information from the local wholesalers, but had to go directly to the manufacturer.

For those who do not have the time, inclination or ambition to follow this course, there are noise suppression kits available, consisting primarily of feedthrough capacitors. Instead of the capacitors being selected for any particular frequency, these kits are more of a brute force, general coverage type, and in most cases are satisfactory; however, for those electrical devices not covered by the kits, use feedthroughs.

Radiated *rf* noise. After the conducted noise is suppressed to your satisfaction, connect the antenna. Tune between stations, shut off the noise limiter and listen to the atmospheric and man-made noise. No type of suppression will affect this noise. The only thing affective here is previously mentioned blanker, clipper, etc. Start the engine and see how the noise increases. This radiated *rf* noise is that emanating from your autoelectrical system, and here is where radiated suppression counts. If your receiver and antenna are performing their functions well, the noise should increase considerably.

Now for the radiated noise suppression: First, be sure the receiver or transceiver is properly grounded. Do not rely on the Gimble mount for this purpose. Use broad straps. Two are better than one, and they should be as short as possible. Be sure the bolts used are large enough, and the surfaces clean. Now we look at the engine compartment. First, check the ground strap from the engine block to the frame. Clean and retighten. Install at least one more strap from the engine to the frame at some other point, and perhaps one from the block to the fire wall.

Remember, what is a satisfactory ground for your six or twelve volt system is not good enough for VHF operation. In some difficult cases, it is also necessary to ground the muffler and tail pipe with broad straps, and sometimes it is even necessary to use wheel static suppressors. This wheel static can be detected best if you can find a road to yourself on a warm, dry day. At a speed of about sixty miles per hour, shut off the ignition switch and listen closely to the noise. As the car loses speed, the static noise will decrease and disappear as the car stops.

In some cases, you may have to ground the hood of the car. If so, use broad straps on each side, near the hinges. Make sure the ground connection at the base of the antenna is tight. Remember that a bumper or bumper mount is a very poor mount for VHF. If you must use the bumper, use broad metal straps from the base of the antenna to the body of the car, making them as short as possible.

As you have gathered by now, any part of the car that is radiating *rf* noise must be grounded. One simple way of detecting this is to use your receiver with a random length of coax connected to the antenna jack. At the opposite end of the coax, wind two or three turns of hookup wire, making a coil one inch in diameter. Tape the coax with the coil at the end to a yardstick. You now have an *rf* sniffer. By moving the coil around the car, you can detect areas of radiation.

The high voltage portion of the ignition system is something else again. The most common approach is to use resistor cable from the distributor to the spark plugs. This may be all right for the high frequency bands, but for VHF it leaves something to be desired. We prefer the resistive type of spark plug. The resistor is built right into the plug. Here we hear cries about poor gas mileage, etc., etc., etc. Remember, the purpose of the resistor is to minimize the jagged peaks found in the electrical wave form. If your high voltage is so marginal it must rely on these broad spikes, you have electrical problems. If you are going all out for suppression, there are kits available which will give maximum radiation suppression. Primarily, they consist of shields for the coil, distributor, high tension cables and spark plugs. (If you can stand the tariff).

In mobile noise suppression, how far to go is entirely an individual matter. Also remember, two cars of the same model may require different measures. Antenna location plays some part in the amount of radiated noise pickup. For example, if there is radiated noise leaking around the hood, and the antenna is near this area, you will have noise. However, hiding the antenna

behind the car is not the answer. Suppression at the hood is.

For those of us who must use city streets and freeways, how much suppression to strive for is a question, for nothing can be done about those cars in front, behind, to the right and left of us, except a very good noise clipper, blanker, etc. For those rare times when we get away from it all, and for those living in less crowded areas, use the greatest suppression possible.

. . . K6ZFV

Getting the Most out of Link Coupling

Most of the VHF transmitter designs in the handbooks, and other amateur publications, use coupling links to transfer energy either between stages, or from the output tank, to an antenna of some sort. These links might either be loops around the output tank or linear networks if the tank uses lines. There are good reasons for using a link, including better harmonic rejection because of the lack of capacitive coupling that will pass everything, and maximum power transfer between stages. The added features of better harmonic rejection can be appreciated when we think of the horrors of a good case of TVI (and what that entails in the way of personal diplomacy to quiet the neighbors). Since we all work for the biggest signal we can squeeze out of any one circuit, we don't care to leave part of it in the tank. With so common a circuit in use, it might be nice to know more about it, so you can snow the hams who aren't informed.

What is a link? Basically a link is an impedance transforming device which takes the high output impedance of your driving stage and either transforms it to the impedance of your following grid, or transforms it to an impedance which will match the relatively low impedance at which most antennas operate. Since the transformer has been analyzed rather thoroughly in the past, it might be well to take this information and transfer it to the high-frequency realm of VHF.

A transformer is a magnetically coupled circuit consisting of two conductors in close enough proximity to each other so the magnetic field of one cuts the other. A varying current in either conductor will induce a current in the other. For maximum coupling efficiency, power transformers are wound on a core. Because of frequency considerations at two meters and up, the link can be just a single piece of wire near the high current portion of the plate lines. They both work in the same manner.

Assume the link in the transmitter which you have built is proportioned properly and just go through the ways to make it operate.

Let's draw an equivalent circuit of a link: In this diagram the generator represents the voltage induced in the link through the transformer action caused by the proximity of the output link to the plate lines. R1 represents the series ac resistance of the link, R2 is the load, and the capacitor and inductor represent the series reactances of the loop. According to Kirchoff's voltage law, the sum of the voltage drops across the passive elements in the loop must equal the generator voltage. To get maximum power into the load R2 we have to maximize the voltage across it, since

$$P = \frac{V_2}{R}.$$

Depending upon how you have the link tuned, you might have either series inductive reactance below resonance, or series capacitive reactance above resonance with its accompanying voltage drop. A portion of the remainder of the voltage is dropped across R1, and the rest is across R2. It is an easy matter to get rid of the reactance by making the inductor-capacitor combination series resonant at the operating frequency. We can make the drop across R1 as small as possible by increasing the Q of the network. At higher frequencies rf tends to travel on the surface of a conductor, the familiar skin effect. We have to make the surface area larger, and the easiest way to do this is to go to some sort of strap line for the link inductance. Silver plating is also a help, but if you use copper and polish it so that it is shiny and smooth, then coat it with Krylon, or something similar, so that it won't corrode, you will never notice the difference.

You will notice that we drew the antenna impedance as a resistor. It will act like a resistor if your SWR is 1:1, as it should be if you've been doing your homework and getting your antennas matched. However, most antennas aren't too broad, and will exhibit some reactance before you move too far from the frequency at which you tuned the antenna. No problem, since your

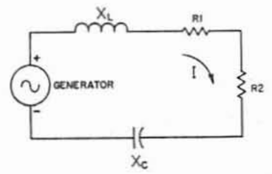


Fig. 1. Getting the most out of link coupling.

link capacitor is variable and you can diddle with it until the link is series resonant again.

Some rigs don't use a series capacitor to tune the output link, but depend on stray circuit capacitance to resonate the affair. This is fine, for one frequency. Unless you have some way to retune the antenna, or use an external antenna tuner, you won't be able to move far from one frequency without loss of power. If you want to spend a little time, you can put in a capacitor, but you probably will have to pull a turn or two off the coil to bring the tuning range of the circuit back into line again. Let's explore the subject a little more.

The maximum power transfer theorem states that, for maximum power transfer to occur, the impedance of the load has to equal the impedance of the generator output; in our case the driving stage. However, if the load is reactive, then the generator has to have a component of reactance equal in magnitude but opposite in phase; i.e., if your load is inductive then the generator has to look capacitive and vice versa. You can still get power into your antenna, but to peak the power output you have to detune your plate circuit a little from resonance to again cancel the combined reactance. This gives your output tube a less than ideal load, and the extra current required for off-resonance operation does a nice job of heating your output stage.

Now, let's see how you tune your transmitter up the right way. If your link is fixed, it's a little harder than if it is moveable (the old guys with their seven-foot high, fifty watters had a good thing going for them). Put your SWR bridge in the forward position, or if you really can't borrow one, whip up some sort of field-strength meter and put it where you can see it while you are tuning up. Energize your rig and resonate the plate; now, peak the output while keeping the plate dipped with your plate meter. If you find that this loads the rig too heavily, *kill the power* and reach inside and pull the link away a little bit from the lines and then go through the routine again. If you do this carefully, you will find that your output peaks at the minimum plate current position. Try detuning the plate circuit a little to see if the power comes up. If it does, it means you still have a little reactance from the link side reflected back to the plate lines. Retune the link a little and try again. Assuming that the lines present a proper load to your output tubes, you will never have to say that "maximum power output occurs just a little off resonance." When you change frequency, just repeak your link and reresonate the plate to keep efficiency up.

A little hint for users of 4X150 series tubes; if your screen current is negative after this peaking process, your link is too big; go to a smaller link and increase your capacity a little.

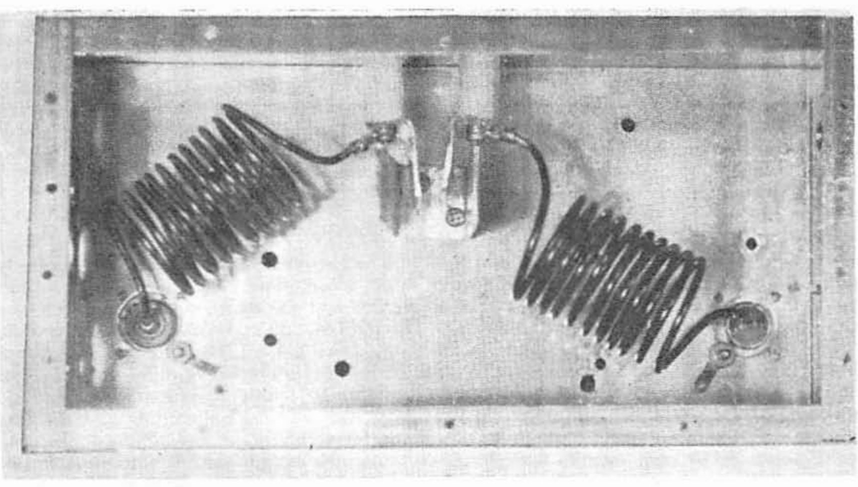
. . . K1GBF

How to Protect Transistors from Overload

Some sad experiences with transistor converters and receivers at my station have resulted in the use of several ideas for protection of transistors which now seem to be satisfactory for most overload conditions. These overloads in the past abruptly ended the useful life of the front end transistor or caused a gradual deterioration of receiver noise figure and loss of weak signals. Four general forms of overload were present at W6AJF. First, a high powered VHF transmitter connected to a beam antenna which was too close to another VHF band antenna and perhaps pointing across the other antenna at times. This would produce a damaging voltage across the input of the first transistor thru the antenna feeder, coax relay and input circuit (low Q) into the transistor even though that unit was not in operation, that is, with no battery connection. For a long time the only protection was to disconnect all antenna coax fittings except for the band in use. A good VHF contest with all antennas connected usually resulted in a frantic search for a new transistor or two.

The dual antenna couplers shown cured this problem since two very high Q circuits added enough selectivity to the transistor converter front ends to knock out this problem. To get very high Q circuits these units have to be large physically, so a second benefit results from their use. Transmitter spurious frequencies are greatly attenuated and the rf energy reaching the particular antenna is confined to that particular band with a reduction of TVI problems in the neighborhood. These dual circuits were built into standard aluminum chassis and fastened on the wall for connection between the coax line of each beam antenna and its coaxial antenna relay. Very high Q is needed to not only reduce transmitting power loss but to keep from losing NF in the receiver. Any loss here reduces the weak signal capabilities so the losses should be kept well below one DB in the two circuits of each coupler.

If each circuit is coupled so as to have a working Q of perhaps 20 and the unloaded Q is perhaps 500, the total coupler circuit loss would be 8% or an efficiency of 92%. The loss in NF would then be less than ½ db. Small circuits cannot be built with high enough Q for low losses, and as much as 2 db is some-



Dual circuit antenna filter for 50 mc used in both transmitters and receiving.

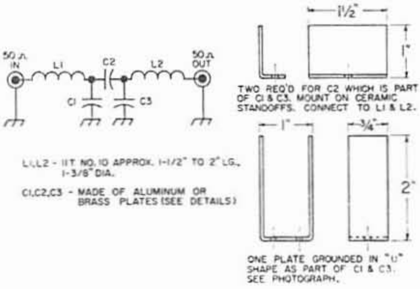


Fig. 1. 50 mc antenna coupler or filter.

times lost in NF if these selective circuits are built into the converter unit.

The second cause of transistor failures is fairly rare. The best protection is still to have all antennas disconnected from all receivers during storms. Lightning protectors in the antenna feeders to a good outside ground may save the transmitters except in a direct hit, but transistors aren't tough enough and out they go even though the bolt of lightning may hit a few miles away. Low capacity fast diodes connected back to back across the first transistor circuit help a little.

The third cause of transistor failure has to do with improper antenna and power control relays. No matter how good an antenna relay is for isolation between transmit and receive positions, an arc at the points will sure put a lot of rf voltage across that first transistor. The answer to this problem is to manually control the relay switching or to use timed delay sequence by electrical means so the antenna relay will be in transmit position before the power relays are in transmit position—and most important, the power relays are "off" long enough for all transmitter rf energy to dissipate in the antenna before the antenna relay is restored to receive position. Antenna relay switching still seems to be the best way of getting those weak signals into the receiver in the VHF region.

A fourth cause of trouble is in the antenna relays because of lack of isolation between the transmit and receive coax connections. Nearly all VHF transistors will break down if the peak input voltage is much over a half volt. Some antenna relays only have about 20 db isolation at 144 mc, or a power isolation of 100 to 1. If you have 100 watts peak transmitter power output, this means 1 watt down into the receiver front end or about 7 volts peak across a 50 ohm circuit. Scratch one transistor! If your antenna relay has 50 db isolation in terms of power, then a KW of peak power would only put .7 volt into the receiver and the transistor might survive. Buy expensive coax relays that have good isolation especially if you operate with high power at 432 mc where antenna relays really lose db's of isolation.

About this time someone always asks why use transistors when tubes will cure this problem in the receiver front ends. The answer is that a recent transistor costing about 52 cents will have a better noise figure than tubes costing 10 to 100 times as much. A lower NF always means more readable signals except perhaps in areas of high man-made noise. Even in high noise level locations, a low NF receiver and noise blanker system will help as compared to the usual NF of a few db higher in the receiver front end.

Antenna relay lack of good receive-transmit isolation can be overcome to some extent by connecting two diodes of low forward resistance, back to back across the input circuit of a transistor. The two diodes should be of a fast type, preferably silicon rather than germanium, with low capacitance such as computor diodes. These two diodes will add a little capacitance to the circuit which can usually be tuned out. The signal loss at microvolt levels is usually quite small and their low resistance characteristics only become apparent at high levels when protection is needed against transmitters or distant thunder storms. Even good computor diodes can be burned out but only at levels many times greater than for a VHF transistor. Occasional checks are needed to ensure that these diodes in a circuit are still in operating condition. A soldering iron, long-nose pliers and an ohmmeter are the necessary test equipment for this purpose. Also be sure to isolate the transistor bias circuits from these two diodes with a small bypass coupling capacitor. They should always be connected across a coil only, with one cathode and one anode to each end of the coil in order to short circuit high amplitude positive and negative rf pulses.

50 mc antenna coupler

The circuits and ideas described previously, were incorporated into four transistor converters and the dual circuit antenna couplers for 50, 144, 220 and 432 mc. The 50 mc units are shown here. The antenna circuit was the result of a number of different dual circuit units at 50 mc. The system shown had the least heat loss for transmitting and the least loss for receiving of any of the more usual forms such as tapped coils with variable tuning capacitors, etc. The input and output coax connectors are in series with each coil which

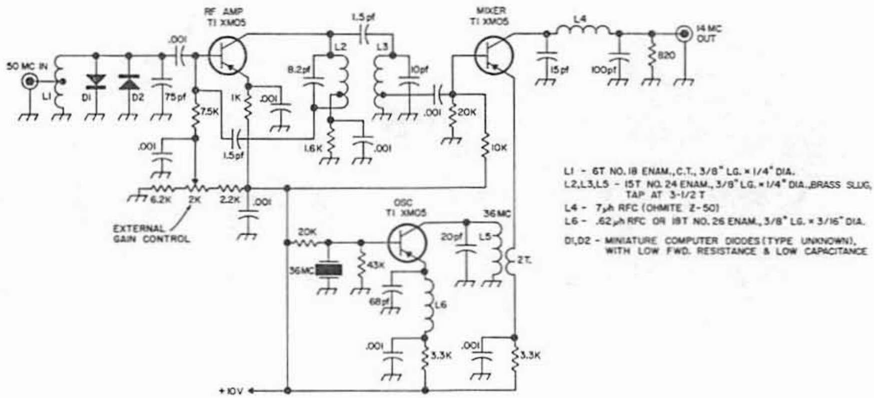
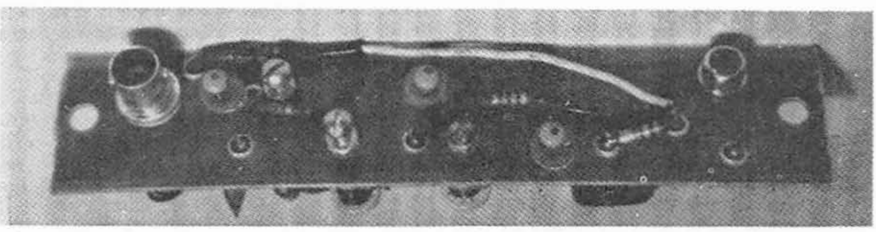


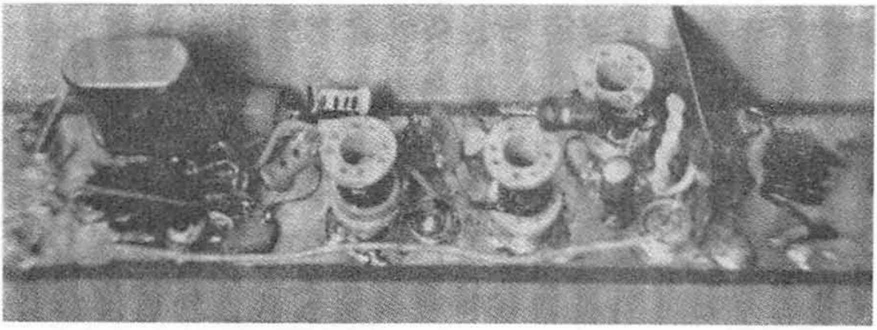
Fig. 2. Low noise 50 mc converter. The transistors are 52¢ TI-XMO5's.

is part of a low C resonant circuit. With the values of C and L chosen, the loaded Q of each circuit is between 15 and 20 which is ample for covering about 2 mc of the 50 mc band. More coil turns and less capacity at the high impedance ends will increase the Q for 50 ohm input and output connections, with a narrower band-width. The tuning capacitors C_1 and C_3 of **Fig. 1** and the coupling capacitor C_2 are made of two small plates of aluminum or brass mounted on 1" x ½" or 1½" x ½" ceramic insulators. The grounded plate of C_1 and C_3 consists of a U shaped bracket of similar metal bolted to the chassis. The insulated plates were each 1½" square with ½" of one side bent at about right angles for mounting on the ceramic insulators. Bending these two plates towards each other increases C_2, the coupling capacity between the two tuned circuits. Bending the grounded U piece sides towards the insulated plates increases C_1 and C_3 and vice versa. Working the coil turns closer together increases L_1 or L_2. All these adjustments can be made when the mounting plate cover is in place since it was made of perforated Reynolds sheet aluminum. A 5 x 10 x 3 inch aluminum chassis (recovered from another project) was used to enclose the circuits. The circuits were tuned up before the whole unit was fastened to the chassis with numerous sheet metal screws.

The tune-up can be done by shorting the coax fittings with a short piece of wire and grid dipping the coils to about 53 or 54 mc with the cover removed, shorting each coil not being adjusted. The next step consists of using a SWR power meter with a transmitter set for 50½ or 51 mc and with the chassis cover in plate. The transmitter is adjusted for maximum power output (plate circuit resonance, etc.) and the SWR reading noted for connection of the antenna feeder directly to the transmitter. The power reading should be noted also for a given value of plate current. Connect the dual circuit coupler between the antenna feeder and the antenna coax relay with the RG-8U coax. The coil lengths and C_1, C_2, C_3 plate spacings can then be adjusted



Top view of 2 x 6 inch board with BNC coax input jack and phono jack output. Unit mounts in 6 x 17 inch chassis for shielding slong with numerous other converters and switching panel.



Bottom view; copper clad side of converter.

in steps with a thin screw driver thru the perforated cover plate holes. The SWR meter on the antenna side of the coupler can be watched for maximum power reading with the same SWR reading as before. If you are lucky enough to have two SWR meters, put one on the transmitter side of the coupler and make sure it reads unity SWR by adjusting the final plate circuit capacitors and the antenna coupler circuits. The final objective is to have unity SWR between the transmitter and coupler with nearly identical power readings into and out of the coupler. The output SWR will depend on the antenna matching at the antenna, not on coupler adjustments. An hour's work or less should result in, for example, 200 watts into the coupler and 185 watts output. For 90% or so of this time, use a large 50 ohm dummy antenna since the beam antenna should only be used for radiating intelligible signals, not as a general test instrument. Once the coupler or "filter" is properly adjusted, mount it in some out of the way place and forget it. It is intended for use on both transmitting and receiving and will add as much as 50 db of image suppression to the 50 mc converter and also reduce reception of unwanted signals outside of the amateur band.

Six meter converter

The 50 mc converter shown in the photographs and in **Fig. 2** was recently built and has a lower NF than other 50 mc converters in use at W6AJF. The new TIXMO5 transistors presently available from Texas Instruments at about 52 cents apiece are very excellent for use at any frequency from 14 to 432 mc. The only disadvantage is that the "plastic" casing cracks easily so either solder them into the circuit carefully or use the new TO-18 type transistor sockets which will fit these tiny transistors. The writer broke several TIXMO5 transistors trying out several in the rf stages of the 50, 144, 220 and 432 converters. In all stages except the input rf stage, these transistors can be soldered into the circuit using a very small soldering iron and supporting each lead with long-nosed pliers as each is soldered to the other circuit components. A small transistor socket is advisable in the first rf stage of any converter since this unit determines the NF and may need changing in time, after a few thunder storms in the area, or transmitter overloads. The input circuit in **Fig. 2** should only be used when the matching antenna "filter" is to be used in order to have good front end selectivity. The loaded Q of the input circuit is about 5 resulting in optimum NF but very little selectivity.

The rf stage is neutralized partially and forward gain control on this transistor permits reduction of rf gain without strong signal overloading and loss of noise figure. Forward gain control actually increases the transistor collector current flow to produce a reduction of gain. The collector series resistor reduces the collector dc voltage at a rate fast enough to reduce the stage gain even though the collector current is increasing. Normal gain control reduces collector current to reduce gain with fixed dc supply voltage. This causes a fast increase of NF and increases the rf stage cross-modulation problems on strong signals many times as compared to forward gain control.

The 10 volt and gain control leads were brought out thru 1000 pf solder-in feedthru capacitors. These same capacitors were used for other by-pass capacitors with some resistors mounted on the insulated side of the 2 x 6 inch copper clad board. The slug coil forms were tapped out for a 6-32 brass machine screw which became the "tuning slug." Normally coils of this type come with regular

adjustable brass slugs or with coded ferrite slugs (white for above 30 mc.) If ferrite slugs are used, reduce the coil turns about 15% or to about 12 turns in the same winding space.

The mixer stage with base signal input and oscillator injection into the emitter, has large enough coupling and by-pass capacitors to act as fairly low impedance to the *if* output frequencies of 14 to 16 mc. The pi network from collector to 75 ohm output jack tunes broadly to around 15 or 16 mc with a 7 μh Ohmite Z500 rf choke and a couple of fixed ceramic capacitors of the values shown in **Fig. 2.** This mixer circuit has very high conversion gain with nearly any good VHF transistor.

The 36 mc overtone crystal oscillator has a semi-tuned emitter circuit which is resonant between the 36 mc desired frequency and the crystal fundamental of 12 mc. This gives regeneration to the oscillator so it will oscillate at the 36 mc. frequency only when the collector circuit is tuned near 36 mc.

A noise generator is useful in tuning the interstage slug coils and the input coil turn spacing. A reasonably good noise generator showed a NF of 2.0 db at 50 and 51 mc and 2.3 db at 52 mc. This should be fine for the really choice dx when the F-2 layer opens up again or at the present time for double hop sporadic E openings.

. . . W6AJF

A Reliable Directional Coupler and VSWR Bridge for VHF-UHF Use

The aerospace industry has fostered the development of many new components and materials. Hams, being the kind of people they are, are quick to see practical applications for these materials that never occur to design engineers.

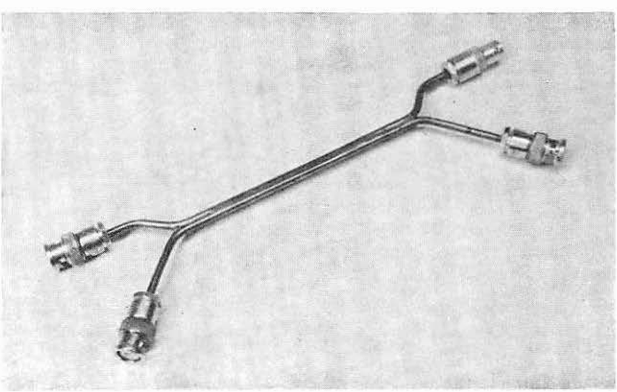
Reliable test equipment for the VHF-UHF bands is difficult to come by on a low budget. The literature is full of "relative" measuring devices but few pieces of homebrew gear are engineered for repeatable performance. Several directional couplers have been built according to this description and each has measured to within ±.5 dB of the designed value.

This is due in part to the mechanical rigidity and close tolerance of RG-141 "coaxitube." No special tools are required outside of a cheap pair of vernier calipers. The tools used to make the original coupler were an Xacto knife, file, soldering gun, vernier calipers and a vise. Don't let the calipers scare you. If you're not after a closely calibrated device they may be omitted.

The design goal was a directional coupler with about 30 dB directivity in the passband with a low insertion loss. Each milliwatt measured at the coupling arm equals one watt through the main line. Such a device is the heart of a good quality VSWR Bridge. The measured values were 30.3 dB coupling and 38 dB directivity at 432 MHz. Data presented in the graph was taken using HP608C and 614A signal generators and a General Microwave R. F. Power Meter. The measured insertion loss was 0.2 dB.

Resolution of the smallest possible VSWR is limited by directivity. Few of the handbook VSWR bridges or the low cost type attractive to the CB trade achieve as much as 20 dB directivity. Thus the minimum discernable VSWR is approximately 1.7:1. With 38 dB directivity, 1.02:1 VSWR's can be accurately measured.

Directivity may be defined as the isolation of arm D from arm A, over and above the coupling as shown in the **Fig. 1.** Coupling is achieved by removing part of the jacket between adjacent coax conductors. If the input is at arm A, incident power can be sampled 30 dB down at arm C but appears −68 dB at arm D. Reflected power entering arm B is sampled −30 dB at arm D while at arm C it is −68 dB. It stands to reason if the directivity is low, one cannot tell with certainty if he is measuring incident or reflected power. Port D may be used as the dc return for a detector at port C and vice versa.



This UHF directional coupler is very simple to make, yet offers excellent performance on the 70 and 23 cm bands.

This device will have its fundamental passband where the length exposed between the two lines is $\lambda/4\sqrt{\epsilon_r}$. It will also have a passboard at $(2n - 1)\ \lambda/4\sqrt{\epsilon_r}$ or at three, five, seven, etc., times the frequency for which it is a quarter wave. Hence a coupler designed at 432 MHz is usable at 1296 MHz.

This coupler has also been used to measure relative power and modulation at 2 meters where its coupling factor for incident power is approximately −40 dB but the directivity is poor, hence arm D must be terminated in 50 ohms. It's a real aid for tune up and will give a good indication of increased power with AM modulation right in the r.f. line. RG141 will handle 500 watts of rf up to 2000 MHz.

The formula for determining coupling length is

$$\frac{c}{4f_0\sqrt{\epsilon_r}} = \frac{\lambda c}{4\sqrt{\epsilon_r}} \text{ or } \frac{300 \times 10^8 \text{ cm}}{4 \times f_0 \times \sqrt{2.1} \times 2.54\ ^{\text{cm}}/_{\text{in}}}$$

$$= \frac{\lambda \text{ c inches}}{4\sqrt{\epsilon_r}}$$

$\sqrt{\epsilon_r}$ for Teflon $= \sqrt{2.1} = 1.449$

From these calculations $\frac{\lambda\text{coupling}}{4}$ at 432 MHz is 4.73 inches. With an Xacto knife cut two pieces of line 8.73 inches long and carefully bend them so that they form the shape shown in **Fig. 2A.**

Clamp the bent coax into the vise and file away the copper jacket taking care that the filed surface is smooth and flat. A belt or stationery disc sander works well too. A cross section of the filed piece should look like **Fig. 2B.** Next fit the two pieces together so that a cross section would look like a figure 8 and secure in a vise. Heat with a soldering gun only. Do not use a torch. Avoid excessive heating. Flow solder between the two lines as shown in **Fig. 2C.** The "arms" can now be bent into any convenient configuration provided enough allowance is made at the ends for connector assembly. A good rule to follow is a minimum bend radius of half an inch although a quarter inch radius is permissible. The arms should be approximately two inches long.

RG 141 has the same cross section as RG 58/U *without* the vinyl jacket therefore any connector that will accept RG 58/U can be used on RG 141 provided a sleeve is made up to make a snug fit in the clamping nut. A special adaptor is made by Kings for this purpose and sells for 45 cents. The connector assembly is shown in **Fig. 3.** Three RG 88E/U and one RG 89C/U connectors were used on the coupler shown in the photo.

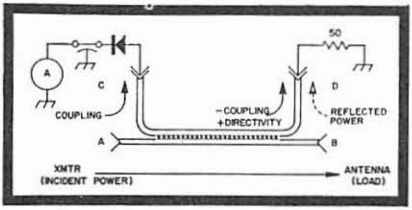


Fig. 1. A typical directional coupler. This device is the heart of a VSWR bridge, and can also be used for many other applications.

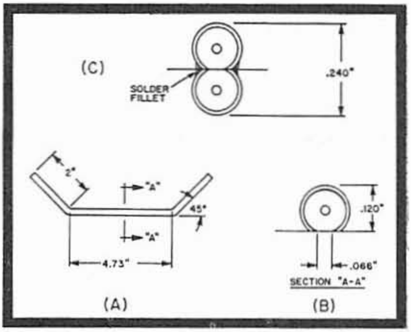


Fig. 2. Details of the construction of the UHF directional coupler.

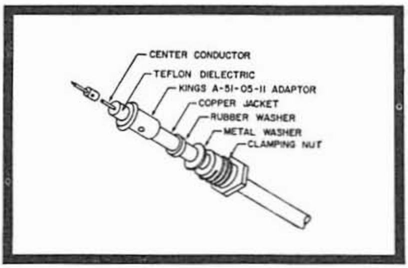


Fig. 3. Use of Kings A-51-05-11 adapter for using GR-141 with standard BNC connectors.

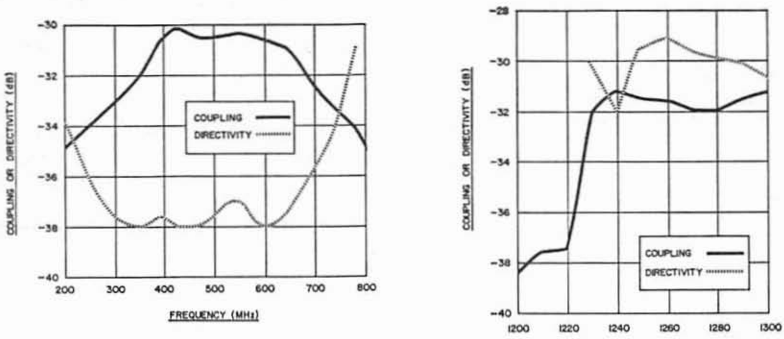


Fig. 4. Coupling and directivity for a directional coupler similar to the one discussed in the text. This device used a coupling wavelength of 4.635 inches rather than the 4.73 inches specified in the text. The only effect of the longer wavelength is to center the curves on 432MHz instead of about 500 MHz.

Fig. 4 gives the measured directivity and coupling for this type of directional coupler at both 70 and 23 cm. You can see that performance is quite satisfactory.

Fig. 5 lists a number of applications for a directional coupler. The detectors in the measuring instruments should be suitable for use at 500 or 1300 MHz.

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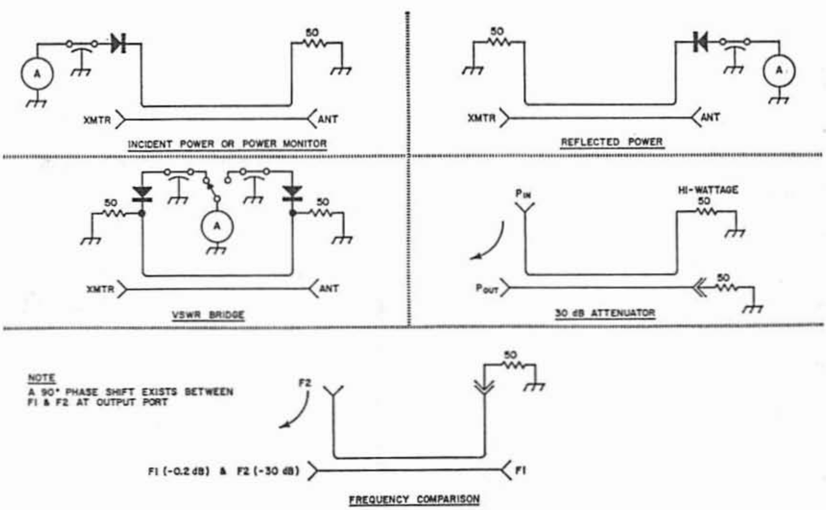

Fig. 5. Applications of the directional coupler described in the text. Unlike most pieces of ham-made test equipment, this one is good at 450 and even 1300 MHz.

Wide-Range VHF-UHF Dipper

Most dippers for amateurs not counting the $400 ones, stop around 200 MHz just as you are about to enter the fascinating UHF region.

After all these years of "grid-dipping" we find ourselves without a grid; so it just becomes a "dipper". To retain the prestige of a hyphenated name we can call it a "dipper-generator". Most grid-dippers have been used as generators, but this one has built-in modulation, variable input-output coupling, controlled Q, and several other interesting features. Best of all, it goes all the way up to 1296 MHz.

When this little unit is completed it may be used as a dipper for determining the resonant frequency of VHF and UHF circuits, as an indicating frequency meter with an adjustable Q-multiplier, a field strength meter and modulation monitor, a sensitive regenerative receiver, or a CW and MCW signal generator. You can also use it as a harmonic monitor or as a frequency transfer unit from one transmitter to another.

Several circuits must be considered when building a wide band instrument such as this. For example, you should change circuits around 100 MHz and again at 600 MHz, give or take a few hundred. Below 100 MHz coils are good; from there to 600 MHz you can use ¼ wave resonators, and after that the ½ wave job becomes rapidly the best method, up to 1300 MHz.

Plug-in rf heads

We have made no attempt to cover the complete range from 130 to 1300 MHz with one oscillator. By using plug-in tuners you may vary the components to suit the frequency. On 50 MHz for example, you may use a low cost transistor, a coil, and a 25 or 50 pF capacitor. From 100 to 600 MHz you use a better transistor, a ¼ wave strap, and a 10 or 15 pF capacitor. In the microwave region up to 1296 MHz you use the best transistor you've got, ½ wave lines, and a small butterfly capacitor of 3 to 5 pF.

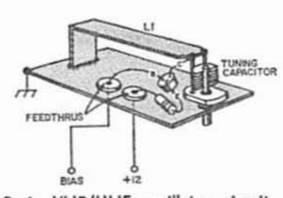

Fig. 1. Basic VHF/UHF oscillator circuit.

If you break the circuit at the right point, it simplifies things—then the two halves may be connected through a miniature 7-pin socket and plug as shown in Fig. 2. All four leads are reasonably dead to rf. You can leave out some of the audio if you like, but it's very handy to have a modulated signal. If you're running triple or quadruple conversion, it's nice to know by it's modulation which is the signal and which might be a *birdie*. As far as dials are concerned—it makes calibration and reading a lot easier to have only one band or range per dial.

130 to 300 MHz oscillator

Fig. 1 shows the basic ¼ wave circuit; Fig. 2 the complete rf unit with control, af output and modulation.

The circuit itself is very simplified, as seen in Fig. 1; there being only one inductance, L1, and no choke coils. This should make for a flat tuning oscillator without power dips as it is tuned over a 2 to 1 range in frequency, and it does just that. With a 2N1726 in the circuit there is a smooth power output curve from about one volt rf at 130 MHz down to ½ volt at 300 MHz.

The rf coupling jack J1 couples the rf energy both in and out. This is because L1 acts as either a detector resonator or an oscillator resonator, as required. Actually this rf jack can be used as shown in Fig. 2. P1 is a variable link to L1 and is plugged into J1; J1A has a few inches of cable between the white ABS plastic front panel and the copper clad bakelite sub-panel. Because the phono plug is rotatable, a nice

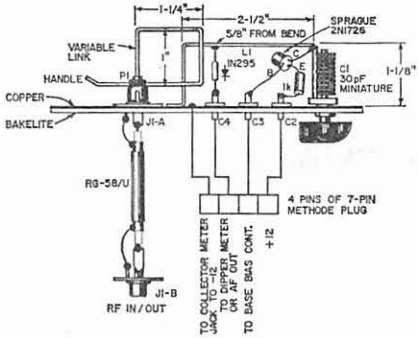

Fig. 2. 130 to 300 MHz tuning head.

variation in rf coupling can be obtained. The coax cable and J1B get the rf out to the front panel for easy use with antennas, probes, cables, etc.

The emitter goes to a 1K resistor then through a coaxial bypass capacitor which gets the dc in and out and leaves the rf behind. These feed-through type bypasses are very necessary—do *not* skimp on this item.

300 to 600 MHz unit

Fig. 3 shows that this unit is essentially the same as the last, except for dimensions. I used a 2N1141 here although many others will work too. It tunes smoothly from 300 to 600 MHz; use the variable link feature as in Fig. 2.

900 to 1100 MHz

For this frequency range we need a little different approach. From Fig. 4 we can

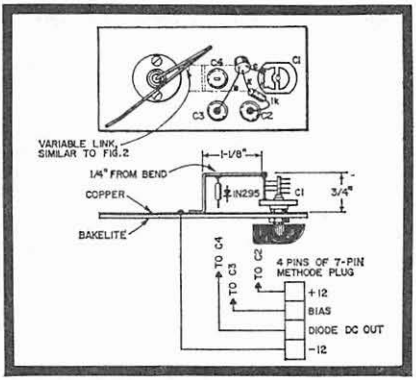

Fig. 3. 300 to 600 MHz oscillator with variable link.

see that we now have two ½ wave lines on which low-voltage points can be found to attach the base and collector resistors. Most of the ¼ wave portion of the lines on the transistor end are actually inside the case. The places where the base resistor and the 500 ohm collector resistor are attached to the ½ wave lines can be found, or checked, by watching the rf meter and touching the lines with a pencil. At the proper point no change occurs in the rf output; sometimes it even increases.

The diode circuit of Fig. 6 is not ideal but it works. Even ordinary hook-up wire will support the assembly of Fig. 6 about ¼ inch below the rf lines; you will soon find the best spot with the unit oscillating. The rf input jack and associated loop L3 are fastened so that L3 is in place over L1 and L2, and it's coupling can be varied in a semi-fixed fashion.

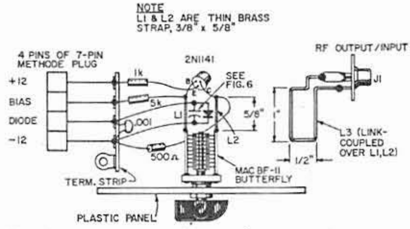

Fig. 4. 900 to 1120 MHz oscillator circuit.

At this point we should mention that as a "dipper" the circuit is still working fine; also as a signal generator. It also serves as an rf detector but as the frequency gets up into the microwave ranges it is not quite as good.

Ideally, you should use the dipper on microwaves as a modulated generator and couple it into the unknown circuit; then a probe attached to *another* tuned detector should be coupled into the unknown circuit. There are quite a few variations using the dipper as an oscillator that you will find useful if you use a little ingenuity.

In the microwave detector line, my experience indicates that the plunger tuned coax cavity line is the best, the tuned trough line next, and the circuit of Fig. 5 next best. As a dipper, generator and regenerative receiver it is still good at 1296 MHz.

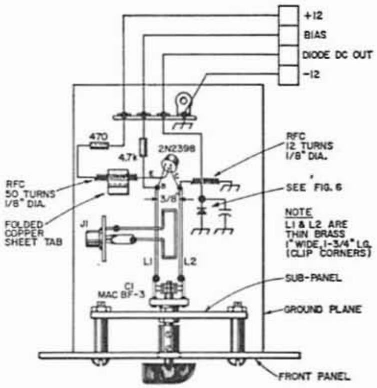

Fig. 5. 1200 to 1300 MHz oscillator and layout.

1200 to 1300 MHz unit

Fig. 5 shows the 1296 unit; This circuit I used a negative dc grounded collector return. Don't short the base plate to the modulator base. Note that one end of the diode is tied to the base plate; this lead is brought out as the minus 12 volt lead. You can also use it ungrounded as in Fig. 4—you can use a 5th lead in the 7-pin plug and keep the diode isolated from the minus 12 volts. Suit yourself, just remember that *all* units have to use the same leads, as they all plug into the single modulator rf unit.

I just plugged a little 12 element Yagi antenna into this dipper and it works nice and smooth as a regenerative receiver. Please note, this is only for test purposes around the shack. You can hear with it, but not *that* good!

I had to put a choke in the cathode lead on this one, and tune it (the choke) with a piece of copper foil. A choke was needed in the collector lead too; after all this is the L-band microwave region.

The rf input jack J1 is mounted on a bakelite upright. Be careful of vertical metal pieces attached to the base plate; they only need to be two inches long or so to become Marconi antennas on 1296! Bring the base resistor and the collector choke away from the lines in a perpendicular fashion—it helps.

The total length of the diode and it's two leads, from ground to the tiny .001 capacitor C2 is about 1⅜ inches; it is spaced about 3/16 from the ground plane. The bottom edges of the lines are about ½ inch from the ground plane.

The transistor presently in the unit is a selected 2N2398; about half of the dozen or so I have here go to 1300 MHz, a couple go to 1400, and the rest to 1100 or 1200.

Don't be alarmed that L1 and L2 are longer than those of Fig. 5, the smaller butterfly capacitor does that. You can make a choice as to capacity, length of brass, and desired rf range. You can use a 5 or 10 pF capacitor for C1, shorter lines, and tune over 1300 MHz. In fact, I have reached 1600 MHz with this circuit!

Modulation and control

Fig. 7 shows the circuitry for bias control, modulation and audio. Don't let it scare you. It's just the same old deal of doing what has to be done for control purposes, and from then on just turning the knobs to get what you want.

I have found that a very good plug and jack can be made by using an ordinary 7 pin socket and a Methode 7 pin bakelite plug. Unfortunately, I have never found a miniature tube with a bakelite base; they are always made of glass, so you will probably have to buy the 7 pin plug.

The minus 12 volt lead goes to the collector meter jack and then to the minus 12 volt of the power supply. This puts the rf panel ground at minus 12 volts and the audio af panel at plus 12. Of course, you don't have to ground the plus 12 on the audio panel, I just have that habit.

The base return goes through a 5K resistor and then to the bias control potentiometer. The diode dc/af output goes to af jack J2 and the meter M1 through the meter sensitivity control. This potentiometer is selected to suit the meter; I have used a 10 K unit with a 500 microampere meter. Note that part of this resistor should be used when af output is desired, otherwise the meter shorts out the af.

Audio modulation

Fig. 7 is the oscillator circuit. The modulation may be adjusted to exactly 1000 MHz. This is very useful as many microwave test amplifiers have built- in narrow band af audio filters centered on

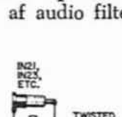

Fig. 6. RF detection loop for half-wave oscillators.

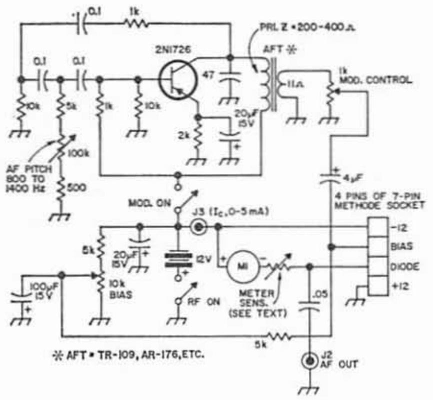

Fig. 7. Power control, modulation and audio circuitry. This circuit is used with all the rf heads.

1 KHz. There is also a modulation gain control. This helps if a nice tone is desired.

Almost any small transistor output transformer will do the job for the af transformer, but don't go over 400 ohms impedance in the collector winding. Note the 1K resistor between the collector and the phase shift network; this reduces feedback to the base and may have to be increased or decreased depending on the gain of your transistor at 1000 Hertz.

Usually you can run the rf current (collector dc) between one and two mils with the 2N1726 transistors; other transistors may take more. A number 48 bulb in the collector lead may save you a $3 transistor. With the 2N1141 the rf output keeps climbing up to 4 or 5 mA collector current. You will readily find the best place to operate. When the collector mils keep climbing and the rf output starts to drop off, back off!

Operation

Dipper

As a general rule "dipping" is easier in the VHF region and gets more difficult as you go into the microwave region. On HF you couple one coil end on to the other; on VHF you bring it near, and on UHF you have to work to get the necessary coupling or use a probe.

With nothing near the dipper, swing the dial through the range to make sure it has no dips of it's own. The VHF/UHF units without chokes described here do not generally have such dips. Unwanted dips can be caused by chokes, resonant feed wire lengths, metal supports, and rf links and cables among other things.

When you do get a dip after coupling to the unknown circuit be sure and change the resonance of that circuit for a final check while watching the dipper meter. If the test circuit is a tuned circuit vary the tuning and see if the dipper will follow it—it *should*. If all else fails, use the dipper as a generator. Since it is very difficult to get the far end of a cable matched exactly over much of a frequency range, *expect* to find external dips in the dipper when using a cable.

Indicating frequency meter

Always keep the transistor plugged in and the base bias at zero so the diode is doing the work. When you advance the bias, collector capacity will cause the dipper frequency to change a little—more with some transistors than others.

For finding a weak signal you can use regeneration by turning up the base bias, but watch out for slight frequency changes. This regeneration can be very handy for finding weak oscillators or hard-to-find rf energy. Use the rf input loop with care; the least coupling is the best. Remember that some cables and terminations will detune L1.

Field strength meter and modulation monitor

The first part is obvious; use a small antenna or probe, get some signal in, and go ahead. Do not use any base bias to start with. If you are working with a very weak signal you might have to push the bias up for regeneration.

The modulation monitor is simply an often-described system of diode detector, transistor amplifier, and padded ear-phones. You can actually hear what your own transmitter sounds like to others.

You don't need much of an antenna or probe when listening to your own rig; don't overload the diode when checking modulation. In fact, use light rf coupling and plenty of audio gain to hear yourself as others hear you.

Regenerative Receiver

Plug an audio amplifier into J2, Fig. 7, advance the bias control, and tune.

One nice feature of this circuit is that the regeneration turns into oscillation very smoothly. Stability is good too. You can heterodyne a crystal controlled two meter signal and copy CW with it. Not bad for a 144 MHz blooper!

To transfer signals from one transmitter (A) to another (B), just tune in A, then

shut it off; listen for B and tune it in. That's all. Harmonic monitoring is easy; just tune over the suspected range in the regenerative condition. It is particularly good because only *one* frequency is present in the receiver. This is *not* the case when using a super-het receiver for monitoring harmonics.

Signal generator

One of the big features of this circuit is the presence of an rf meter right in the proper place circuit-wise. The modulation also helps, especially when running triple or quadruple conversion in a receiver. The modulation control is very convenient, at full on its spreads the signal across 20 or 30 kHz on a selective receiver. For checking a difficult to get at circuit, use a cable and probe, either capacitive or inductive, to get the signal into the unknown circuit.

One of these units can be used for antenna and receiver tests. I just plug a little two element beam into the rf jack and set it out away from the shack; often one or two hundred yards away. There is nothing like tuning up pre-amps with your antenna system connected. For antenna tests it is used in reverse.

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VHF-UHF Mixers

Here is a series of handy-dandy little units which you will find very useful for picking up such signals including the desired ones, and for watching small amounts of rf volts like from transistor multipliers before they are full-grown. We will describe some for lower frequencies also because they will do things which the usual run of grid dippers do not, such as serve as mixers or video detectors.

Of particular interest I believe, should be the 400 to 500 megacycle unit, which makes an awfully nice mixer for the 432 band, and also for amateur Tee Vee.

General Purpose Untuned Detectors

Fig. 1 shows a little gadget of great utility around the shack bench. The input capacity, the choke, the rf bypass C3, and the dc load, R1, should be of different values for different groups of frequencies for best results. In the *if* regions you can use .001 mfd for C1. In the HF range 3 to 30 megacycles, use a 7-45 mmfd mica trimmer and from then on up use a small .8-7 mmf one, with the adjusting screw end connected to the choke rfc. That is, leave the smallest amount of metal connected to the test point. Also, use "pee-wee" alligator clips. C2 is a ground isolating capacitor. Lets you connect the gadget across a plate coil with B plus on it. (Not a kilowatt tho!)

Rfc can be a Tee Vee peaking coil for use on the *if* frequencies. Even an old audio transformer secondary can be used when using this gadget around 2 kc. For the HF regions use a "standard" 2.5 mh choke. For the UHF region wind your own. About six pi sections of 5 turns each no. 34 to 36 wire is good, on a ⅛ inch form. Put your finger on it once in a while if in doubt. If that does anything except decrease the output meter, use more wire!

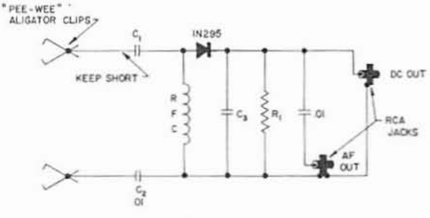
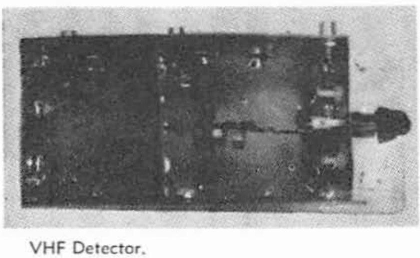


Fig. 1—General Purpose rf Detector

R1 is not really needed if you only use a meter with this unit. The moment you want to listen though, it is necessary. Anyway, you ought to get familiar with what makes a good AM diode detector-demodulator. Around 300k is good. For "video," R1 gets real small.

C3 also depends on usage. For measuring you can even slow down your meter action if you use many mfd's. Seriously, a good value for AM voice demodulation is 500 to 1000 mmfd. You leave this in for most everything except video. You might use as little as 10 mmfd there. C4 is just an af coupling. Use .01 for video; this may go *up*. Remember, 30 cycles? So, enough on this one. You can see there is quite a lot to even the simplest gadget, if you want to cover the foul lines as well as left field.


VHF Detector.

VHF Tuned Detectors and Mixers

Fig. 2 shows the essential details. A unit useful from 6 to 2 meters is shown first mainly for description purposes, although when a special frequency detector or mixer is needed for VHF it is very nice to have one handy. Some interesting experiments can also be done on wire wound coils versus "helix" coils.

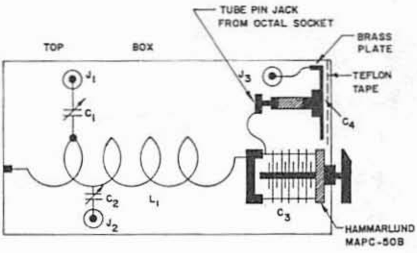


Fig. 2—Side View, VHF Detectors

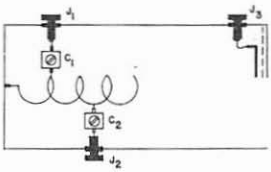


Fig. 2B—Top view

The box, not quite yet a trough line, is made of standard (for this experimenter) copper-clad bakelite, and can be fitted with a top cover which does not change results much except to cut down rf leakage. All rf and *if* components are kept inside and shielded, with feed-through and leakage in mind. There are two types of leakage involved; the first concerning the rf under investigation. When magnetic or voltage probes are used on the input jacks for circuit, antenna, harmonic or parasitic energy checking, etc., it is necessary to avoid direct coupling into L1 itself. Otherwise the probe in use will not be able to tell the proper story about what is going on. Also, antenna experiments are often run with long cables so it is of considerable interest to avoid direct pick-up, even of weak signals (and ignition) on L1.

The second leakage is of course at *if*. Note the very simple arrangement to prevent this. The blocking, or rf bypass capacitor C4 is built into the crystal holder (it actually is the crystal holder) and is on the *inside* of the box and close to the output jack. The capacity of this unit is of some interest as it forms part of the tuned *if* output transformer. A word here about crystal mixers. Every time we have used the circuit of Fig. 2 it has worked right away. Refinements can be added or a strictly fixed-tuned converter can be used, but this unit can be made to do almost anything in the VHF-UHF mixer line, especially as a *tunable* front end.

C4 also serves as a dc bypass capacitor when a meter is plugged into J3 for measuring purposes, although you may add more capacity to C4 if you use the unit for dc only.

Note that several circuits can be plugged into J3. The dc crystal current is present, for metering. Different *if's* can be plugged in, as needed, outboard *if* pre-amps can be tested, etc. Fig. 3 shows a "crystal-*if* output box" which is very handy. P1 plugs directly into J3 of Fig. 2. C1 should be large enough to tune L1 to the *if*, including the capacity of C4, and the jack and plug. C2 and C3 may be .01. R1 is "what suits the particular crystal" and the excitation used. I have generally found this to be between 1K and 3K.

Caution! When using high *if*, such as 52-53 megacycles (broad-band), P1 and J3 leads must be kept real short. 50 megacycle circuits do *not* like to be tuned through long leads. You will be baffled by the most peculiar sort of mushy, backward, (just plain lousy) tuning you ever saw. Like when you have a FB capacitor with a couple of good clip leads about four or five inches long, and it works fine on tuning coils around 5 to 10 megacycles, but up on 6 meters it just goes Blah! Of course you can build the *if* output circuit in another box right alongside of the Fig. 2 box.

You may not like all this experimentation at every step, but if you do go through with it you *will* learn some practical matters about VHF and UHF detectors and mixers! We are actually not getting into the theory of mixing at all. This *really* gets deep if you do delve into it.

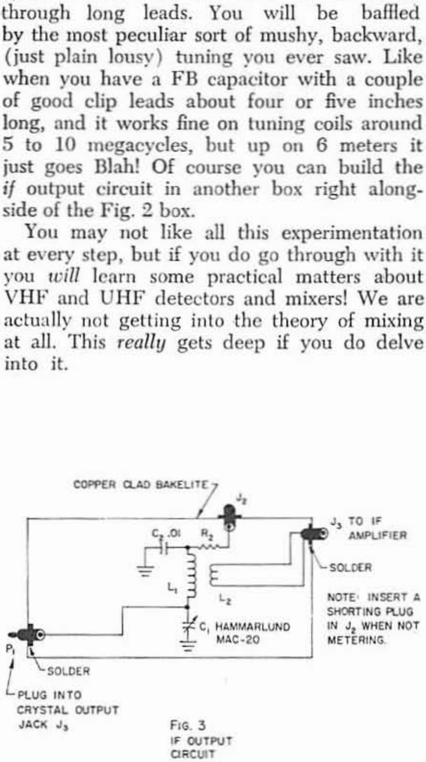
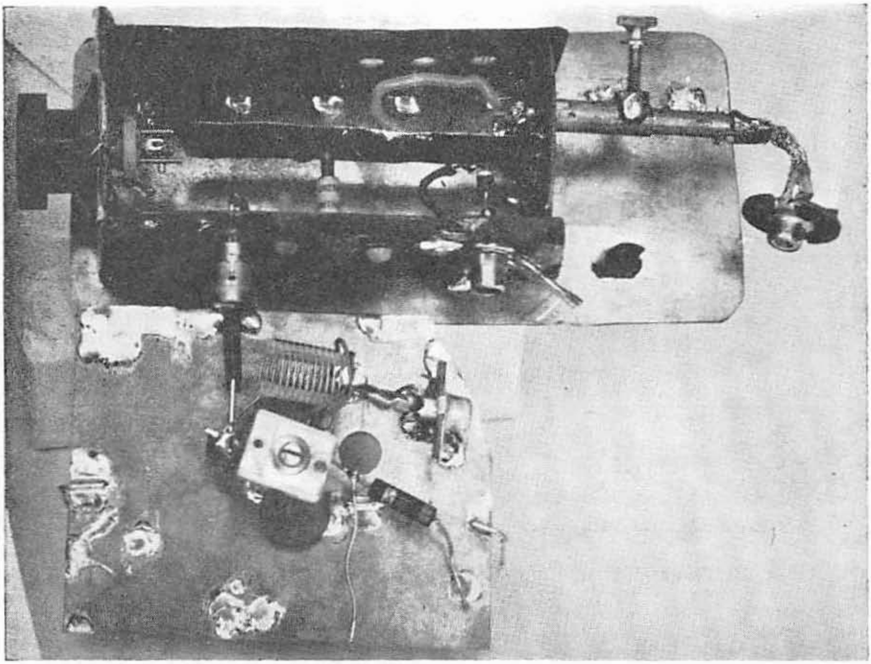


Fig. 3—if Output Circuit



400-500 mc detector-mixer at top. IF output at bottom.

Just for fun, and to check a crystal mixer on HF, I put into the box of Fig. 2 a 32 turn coil of 16 turns to the inch airwound, for L1, tuned by a 50 mmfd capacitor for C3. It tuned from 12 megacycles to 35 megacycles and sure pulled in 20, 15, and 10 meter amateur stations (and a lot extra as well) using a signal generator for the local oscillator, plugged into J2.

The *if* was tuned to 3.49 megacycles and used the circuit of Fig. 3 with two inches of 32 turns-per-inch *if* coil tuned with about 140 mmfd for C1.

Incidently, C4 in Fig. 2 was tested to be 75 mmfd. That is, with a somewhat loose brass plate for the crystal holder-output capacitor asembly. Two layers of sticky Teflon tape were used for the insulator of C4.

With 11 turns of 6 turns-per-inch airwound coil for L1 of Fig. 2, the circuit tunes to 6 meters. With 4 inches of straight copper wire for L1 it tunes from 75 to 200 megacycles, still using the 50 mmfd capacitor. Now watch! Just taking out the straight heavy wire and putting in copper strap (also 4 inches long) in its place, changed the tuning range to 80 to 250 megacycles. See also later paragraph on "Helix" coils.

Putting in a small Johnson type 9 mmfd capacitor, the same circuit tunes from 165 to 285 megacycles using a 5¼ inch strap 1 inch wide. Putting a top cover on the box, the range went to over 300 megacycles but did not change power much.

Now for wire versus "Helix" coils. Of course, a Helix Coil sounds a lot more impressive than a strap coil. Suit yourself. The circuit of Fig. 2 lends itself well to this check. L1 has only two major connections, except for C1 and C2 which are easily soldered on. As an alternative, J2 (or J1 also, see also the UHF tuners) may feed a loop coupling to L1. In fact, for best tuning range, use coupling loops. See Fig. 4. As an example of wire versus strap, L1 was made of three turns of heavy copper wire, no. 14, and tuned 120 to 210 megacycles using the Johnson 9 plate capacitor 9 mmfd, with a box 3½ inches long by 3 wide by 3 deep. Just changing to three turns of ¼ inch copper strap makes the tuning range from 160 to 280, with the 220 band right in the middle of the range. The copper strap coil is about 9/16 O.D. and is about an inch long, with some 3/16 spacing between turns. It is air supported and there are about

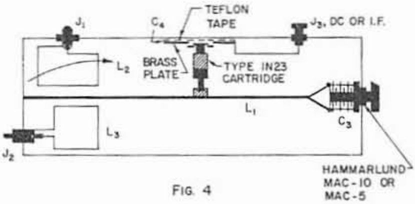


Fig. 4—400 to 500 mc Detector-Tuner-Mixer

⅜-inch straight copper straps as leads on each end.

And Now For 432

There have been quite a few circuits shown for 400 megacycles. Some of them show various kinds of small coils, loops, and what have you—attached to a crystal mixer, in one way or another. Plenty of tube mixers have also been described, but here we will concentrate on crystal diodes since they are simple and effective. At any rate, our thought here was to make up a tuned rf detector that would serve also as a mixer, be sure-fire and fool-proof, and be low in time and cost demands. We have already made one that works FB as mentioned above, but is a coaxial unit.

Fig. 4 shows the result of this easier-to-make trough-line venture. It tunes from under 400 to over 500 and covers RADAR, amateurs, RADAR, mobile and CB bands (UHF), and takes in the first few UHF Tee Vee channels. It works FB as an rf power detector and also as a mixer, *now*, but it has been a battle to get the latter fool-proof. First, as a detector. No trouble here. Again, the influence of the wide strap for L1. Using a one inch wide strap for L1 pushed the frequency quite a way up and increased the Q. Using a regular "store-bought" tuning capacitor for C3, a Johnson 5 plate type (I believe it is about 9 mmfd at maximum) it tunes excellently, going from under 400 to over 500 megacycles. It pulls in Radar (of course) with only an af amplifier plugged into the output jack. It works a meter FB, showing several volts dc from a small transistor UHF signal generator.

The position of the two input jacks and their taps on the main tuning strap, Fig. 4, was carefully tested. Be careful on this! A small loop of wire at L2, grounded at one end and terminated by an *open* jack resonates right in the middle of the band. This is an ASB-7 using 55 megacycle *if* for the first section, then changing to 15 megacycles. It was built by G.E. during WW2 and still works good. Using a transistor local oscillator tuning 450 to 550 megacycles, the ensemble makes a very interesting tunable receiver for the range 390 to over 500 megacycles.

An interesting item concerns loading with the two inputs variable as shown in Fig. 4. A signal on J1 produces 3 volts dc out of J3. That is, when the J2 loop L3 is *decoupled*. See also Fig. 5. When a resistor is placed across J2's output cable and L3 is coupled *into* the magnetic field of L1, the output voltage drops to 1½ volts. A matched 432 megacycle antenna has the same effect. As a mixer, the two variable coupling loops work like little charms. With the set up I tested. The oscillator loop needed to be only about ½ coupled, that is, at about 45 degrees. One thing was sure, you could now maximize the antenna and the oscillator injection coupling. This was using a tuned transistor local oscillator.

Antennas get to be a problem with 100 megacycle tuning range. Using an indoor dipole, several very loud 450-470 mega-cycle stations were heard—probably in the mobile business, or UHF CB bands. For ATV this unit should be very FB. Bandwidth can be adjusted, antennas matched, video and sound outputs tuned up, etc.

If you have a good strong power oscillator for 440, these two should be ideal for good power on ATV.

Some details now on the two variable coupling methods. Mechanical, mostly. Fig. 5 shows one method of obtaining variable loop

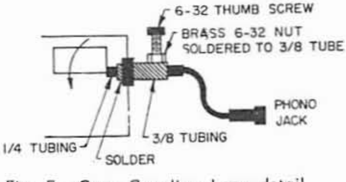


Fig. 5—Coax Coupling Loop detail

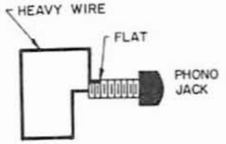


Fig. 6—Phone Jack Variable Coupling detail

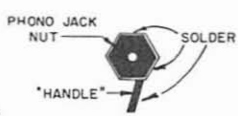


Fig. 7—Locknut detail

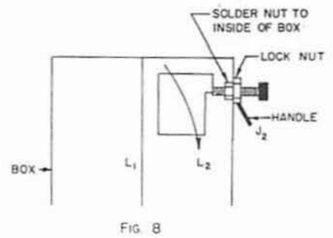


Fig. 8—Phono Jack Variable Coupling detail, top view

coupling. A one inch section of ⅜ inch copper tubing is drilled out for a 6/32 thumb screw and a brass nut is soldered onto it. A two inch long piece of ½ inch copper tubing is prepared with RG58/u inside, first removing the black cover. Feed it into the ¼ inch tubing and remove about two inches of the tinned copper braid. The insulated center wire comes out of the ¼ inch tubing just inside the rear wall of the box of Fig. 4. It forms a loop roughly ¾ inch long by about ⅜ wide, and should turn freely in the space between L1 and the inside of the box. From tests, this loop could be even smaller.

The second method tried goes quicker and works the same. Suit yourself. A phono jack, single mount type, is prepared by filing a slight flat on the tip of the thread. See Fig. 6. This serves to solder the ground return side of a loop. See also Fig. 4 again. A phono jack nut is soldered to the inside of the box wall, over a ¼ inch hole in the same wall. Another phono jack nut has a heavy wire loop soldered around it to form a handle for using it as a locking nut on the outside of the same box wall. See Fig. 7. The whole shebang is shown in Fig. 8. Looks kinda crude but works like a charm. Where can you *buy* one like it for 432? You have to file everything nice and flat on that assembly, by the way, or you can't get both nuts on and working right.

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